

Manufacturing Data Exchange Specification

Simplifying Manufacturing Data Exchange

ModuleWorks GmbH

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Release History and Outlook

Release	Scheduled	Released	Description
0.9.0	2023-09-07	2023-09-07	Preliminary release, including basic concepts to gather feedback and prepare production release
0.9.1	2023-10-15	2023-10-16	ISO compatible parametric cutting tool models for solid end mills Introduction of container format Simplifications: - Removal of Line from Contour - Removal of List Elements Removed Changed by column from release History (new releases are updated by ModuleWorks GmbH) Minor Improvements
0.9.2	2023-12-01	2023-12-01	Improvements to arc definition in contour XSD file for XML validation Change Custom Attributes to enable XSD validation Introduction of ConnectorReference Minor Improvements
0.9.3	2024-02-01	2024-02-01	Addition of flute_count & hand to tools Minor Improvements Candidate for Version 1.0.0
1.0.0	2024-04-01	2024-04-02	Change CuttingCondition enum to lower case to match all other attributes Added description of versioning and compatibility between versions Added further information to some optional tool parameters Minor editorial improvements
1.1.0	2024-06-01	2024-06-03	Addition of the following attributes: - flute_helix_angle and rake_angle_axial for CuttingTools - connection_code_machine_side for AdaptiveItem Addition of ParametricToolType ProbeWithStraightShank Minor specification improvements for the parametric tool descriptions Layout change of the specification to support publishing as PDF as well as HTML
1.2.0	2024-08-01	2024-08-01	Addition of the following attributes: - process_type for ModelCuttingTools and ParametricCuttingTools - connection_code_machine_side for ParametricCuttingTools and ModelCuttingTools - connection_code_workpiece_side for AdaptiveItem Addition of ParametricToolType ThreadMillSingleForm ISO compatible parametric cutting tool models for drills and countersinks

Release	Scheduled	Released	Description
			- TwistDrill - SpotDrill - CounterBoreDrill - CenterDrill
2.0.0	2024-10-21	2024-10-21	Align casing of some attributes to snake casing: - flute_count - cutting conditions (none_spinning, both_spinning, spindle_spinning, stock_spinning, lathe_drilling) Fix small bugs for ConnectorReference: - now optional in Constraint - carries no own CustomAttributes anymore, since it is only a reference to another entity. Forward/Backward compatibility: - MDES compliant readers ignore unknown entities - MDES compliant readers ignore unknown enum values for material_system & hardness_system
2.1.0	2024-12-01	2024-12-02	ISO compatible parametric cutting tool models for drills and countersinks - Step Drill - Tapered Countersinking Drill Addition of ParametricCuttingInsert and ModelCuttingInsert Addition of the following attributes: - draft_angle for ExtrudedGeometry ISO compatible parametric models for regular inserts: - Parallelogram Insert Added AxisOffsetValue (Linear and Rotational to Constraints) Fixed ambiguous wording for flute_count, mesh_folder_index, tool_number to only carry 0 or positive integers
2.2.0	2025-02-01	2025-02-03	ISO compatible parametric models for regular inserts: - Triangular Insert - Trigon Insert - Round Insert Parametric models for irregular inserts: - Kite Insert The parametric model for TSlotEndMill now features optional parameters for the upper cutting contour. Parametric cutting tool models for solid end mills: - Lollipop Mill
2.2.1	2025-06-01	2025-06-01	Future releases will be done in April, August and December.
2.3.0	2025-08-01	2025-08-01	ISO compatible parametric models for regular parametric inserts: - Square Insert - Rhombic Insert - Pentagonal Insert - Hexagonal Insert - Octagonal Insert Parametric cutting tool models for: - Cylindrical Reamer - Thread Cutting Tap With Shank - Barrel Mill Addition of the following attributes: - nc_tool_number & nc_tool_id for tool components

Release	Scheduled	Released	Description
			- max_ramp_angle for ModelCuttingTool & ParametricCuttingTool Changed parametric cutting tool parameter ThreadsPerInch to accept a Float instead of Integer For ParametricCuttingTool the parameter KCH/CHW should always be used together Added MachineSide & WorkpieceSide options to the direction Enum (MS & WS will be removed in version 3.0.0) Shankprofile parameter of ParametricCuttingTools was dropped in favor of using an AdaptiveItem Minor Bugfixes and Improvements e.g.: - fixed spelling of ParallelogramInsert to be consistant throughout the specification - deprecation of NonRevolvedModel of AdaptiveItem (use Model instead) - deprecation of ThreadCuttingTap and its parameters (use ISO conformant ThreadCuttingTapWithShank instead)
3.0.0	2025-12-01	2025-12-01	Addition of the following ProcessTypes: - MillTurning - LatheDrilling - Probing - Shaping - Grooving - NoTouch Multiple process types can be supported Cutting conditions have been deprecated in favor of ProcessTypes: - noneSpinning -> Probing - stockSpinning -> Turning - toolSpinning -> Milling - bothSpinning -> MillTurning - latheDrilling -> LatheDrilling Added new geometry types Sphere & Capsule ParametricCuttingTool & ParametricCuttingInsert have Material as optional Child AdaptiveItem has a new attribute stacking_group (Holder / Arbor) ° is deprecated in favor of deg to specify angles in degree ISO compatible parametric cutting tool models for - CoreDrill Minor Changes/Bugfixes: - DCORE of ThreadEndMillWithDrillingPart is now a required parameter - fixed missing nc_tool_number & nc_tool_id for ToolAssembly - changed parameter requirements for Lollipop mill -> APXM is required now, DC & DN 1 of 2 optional - Forward-Compatibility covers all extensions of existent enum types - LSN added for CounterboreDrill, StepDrill, TaperedCountersinkingDrill, SpotDrill, TwistDrill, CenterDrill - DCINTF added for ThreadEndMillWithDrillingPart allowing for a flat tip - Specified that, if parameters overspecify a tool, they must refer to the same geometry - Introduction of numerical tolerances: Values/Differences smaller than 1e-12 are regarded as 0 - Revised additional rules for DieEndMill to better capture different scenarios of contour construction Removed deprecated entity NonRevolvedModel & enum-values MS and WS from enum direction

Release	Scheduled	Released	Description
			Removed unspecified tool type ThreadCuttingTap and its parameters (use ThreadCuttingTapWithShank instead)
3.1.0	2026-04-01	2026-04-01	Added hand attribute to ModelCuttingInsert and ParametricCuttingInsert Added new geometry types Torus, Ellipsoid & NURBSGeometry Added KCH, CHW, DCINTF and THSL to Thread Mill Single Form, allowing for a drilling part NCToolNumber is deprecated in favor of NCToolID Minor Bugfixes and Improvements e.g.: - Added recommendations for sensible attribute values of primitive geometry types - Added a remark regarding the HeadLength of Ball-Nosed End Mill - Removed nc_tool_number/id erroneously present on SetupAssembly level - draft_angle attribute is now optional (ExtrudedGeometry) - Added remarks regarding the Arc2D contour element - Added SMIR (MirrorBaseShape) parameter to Parallelogram Insert accounting mirrored Base shape
3.2.0	2026-08-01	2026-08-03	Added parametric cutting tool model: - Drilling Thread Whirler Minor Bugfixes and Improvements e.g.: - Clarified meaning of the Transform residing on Nodes in Assembly trees - Corrected the description of Constraint: It can have multiple AxisOffsetValues - Corrected a typo in workarea_name attribute - Added optional LHN and updated depictions for TSlotEndMill, LollipopMill, BarrelMill and CylindricalReamer - Updated default LS computations to account for head and shank chamfer lengths - Specified that DN is required for LollipopMill if APMX is 0 - Corrected DCD validation for ThreadEndMillWithDrillingPart to use DC instead of DCORE
Future	-	-	DIN compatible parametric models for fixtures

Glossary and Abbreviations

Term	Definition
MDES	Abbreviation for Manufacturing Data Exchange Specification; both the name of the overall Initiative and the actual specification published as part of the initiative
CAM	Computer-Aided Manufacturing; the use of software for the purpose of defining manufacturing strategies within production engineering
CAD	Computer-Aided Design
CNC	Computer Numerical Control; the automated control of machine tools such as mills, lathes, or 3D printers
PLM	Product Lifecycle Management
PDM	Product Data Management
STEP	Colloquial term for ISO 10303 compliant file for representation and exchange of product manufacturing information; Abbreviation for “Standard for the Exchange of Product model data”
XML	Extensible Markup Language; a markup language and file format, which is human-readable, for storing and transmitting arbitrary, structured data
XSD	XML Schema Definition
HTML	Hypertext Markup Language
STL	Short for stereolithography; a file format for three-dimensional models
RGBA	Red Green Blue Alpha; a color model
ISO	International Organization for Standardization
DIN	Deutsches Institut für Normung - German Institute for Standardization
UUID	Universally Unique Identifier

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Manufacturing Data Exchange Specification

This document is intended for everyone who wants to participate in an open ecosystem for data exchange in manufacturing software landscapes. Free to adopt, the Manufacturing Data Exchange Specification (MDES) enables the universal digital description of manufacturing equipment, such as cutting tools, fixtures, and their mounting in machine tools. In the following, the file format and other information relevant to all involved parties will be described.

1.1 The Vision

The seamless flow of data in manufacturing software landscapes is essential for streamlined operations. Many different parties provide software systems for specific purposes throughout the manufacturing process chain. Digital catalogues are used for equipment selection. CAM systems are used to define manufacturing strategies. Complementary systems for verification of manufacturing instructions help reduce operational risks – in work preparation or on the shop floor. However, because these systems are developed by different parties, they usually utilize proprietary data models for the description of manufacturing equipment. To connect these systems, data bridges are built which typically connect a specific source system to a specific target system. Among other things, this approach has the following two disadvantages:

1. Development efforts are necessary for the integration of a new system into the digital thread
2. Maintenance efforts are required whenever an upgrade of a system is necessary

These two factors are significant problems for manufacturing companies who wish to streamline their operations and benefit from the latest developments in manufacturing software systems – such as new machining strategies or improved analytics capabilities. To overcome these limitations, we propose MDES as a universally adoptable description of manufacturing equipment. By implementing MDES, you will not build a point-to-point bridge to a specific target system but gain connectivity to a growing ecosystem of industry players, such as tooling suppliers, CAM developers, CNC manufacturers or machine tool builders. This way, your integration into the digital thread can exponentially scale with the number of MDES adopters. Exemplarily, MDES can be used to facilitate data exchange in the following constellations:

- Transferring setup and tooling data from a CAM system to an offline simulation system in work preparation
- Transferring setup and tooling data from a CAM system to an online collision avoidance system
- Importing tooling data from equipment suppliers into a CAM system
- Importing tooling data from presetters into online collision avoidance systems
- Closing the feedback loop between production engineering and the shopfloor by exporting probed setups from an online collision avoidance system and importing them in a CAM system to fix planning errors

MDES is based on existing industry standards such as ISO 13399 or DIN 4000. MDES is continuously extended to cover new equipment types, new ways of definitions or additional information. MDES is orchestrated by ModuleWorks GmbH, a neutral supplier of toolpath and simulation technologies. MDES is publicly and freely available at www.mdes.info under the terms and conditions stated in the chapter Preliminary remarks. If insufficiencies or deficiencies within this document are discovered, they should be reported to authors via the contact form on the

website to enable a universal solution. The authors are more than happy to implement any reasonable improvement suggestion and look forward to your feedback

1.2 Preliminary remarks

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Version 0.9

Date of Issue 2023-09-07

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General Structure

The file format chosen is a subset of XML as a human readable representation of the data needed to be described by MDES. As such, in the following sections, an overview of the general MDES XML structure is given. Subsequently, a specification of each XML element with its properties is stated. In the scope of an MDES compliant XML file, only the listed elements in this specification with their respective attributes are allowed. An XML schema is provided supporting this specification. Following the XML specification each file must be given an XML declaration

```
<?xml version="1.0" encoding="UTF-8"?>
```

Subsequently, the MDES data description follows. It is contained in the XML root element

```
<MDES version="x.x.x">
```

The entities of the MDES specification are described by unique elements in the XML file according to the standard for XML elements:

```
<ElementName attribute1="xx" attribute2="yy">
  <ChildElement/>
</ElementName>
```

2.1 Versioning

Starting from version 1.0.0 the version numbering follows a fixed semantics. The version numbering is done in the format of x.y.z whereas

- X states the major version of the specification. Changes breaking forward compatibility of the resulting XML file will get a new major version number.
- Y states the minor version. All changes that only get a new minor version number are covered by forward compatibility.
- Z is not used at the moment and is reserved for future use.

2.2 Container Format

As a container format a zip container is used with the file ending “.mdes”. Inside this container an XML file is contained at the top-level as well as a folder with the same name as the XML file without the file ending. In this folder complementary mesh data can be placed as specified below.

2.3 Forward Compatibility

As stated, minor versions are forward compatible. Changes that can occur in this scope are:

- Addition of further XML entities.
- Addition of optional attributes on all kinds of XML nodes.
- Extension of already existent enum types. Those include, but are not limited to:

- Addition of new tool or insert types, i.e. an extension of the already existent enum type of the attribute `tool_type` / `insert_type` (see **Values for attributes**) as used in the XML node `ParametricCuttingTool` / `ParametricCuttingInsert`.
- Addition of new tool or insert parameters, i.e. an extension of the already existent enum type of the attribute `parameter` / `insert_parameter` (see **Values for attributes**) as used in the XML node `ToolParameterData` / `InsertParameterData`.
- Addition of new process types, i.e. an extension of the already existent enum type of the attribute `process_type` (see [Value for attributes]) as used in the XML nodes of `ParametricCuttingTool` and `ModelCuttingTool`.
- Addition of new material systems and hardness systems, i.e. an extension of the already existent enum type of the attribute `material_system` and `hardness_system` (see [Value for attributes]) as used in the XML node `Material`.

Thus, a reader compliant with a specification version of 1.0.0 must be able to also parse 1.1.0 or 1.2.0 and so on.

Therefore, it is allowed to ignore unknown attributes and enum values. An unknown tool type must not be ignored but replaced by the enum value `Unsupported`. Thus, if a compliant library writes a file imported from a higher version number the unknown optional attributes as well as the toolparameters can be omitted, while for the unknown tool type the data is preserved by writing the enum value `Unsupported`.

Further unknown entities can be omitted in forward compatible parsing. In case this yields a faulty state (e.g. in an `Assembly`), the next higher entity (e.g. a `Node`) is omitted as well.

The MDES Elements and Structure

Each element of the MDES specification and its properties are described in the following, after some general remarks to the concepts of the elements have been made.

- Multiple attributes of the MDES elements can have units. Supported units are mm (millimetre) and in (inch) for lengths, rad (radian) and deg (degree) for angles (° is deprecated as of version 3.0.0), HB (Brinell scale) and HRC (Rockwell scale) for hardness.
- Floating point values should be printed with 64-bit precision. The written string must conform to the following pattern representing the value as a number with its base 10 exponent:
 - optional leading minus sign
 - nonempty character sequence of decimal digits (optionally the decimal-point character “.” can be contained)
 - “e” or “E” character followed with an optional plus or minus sign and a nonempty sequence of decimal digits
- Since numerical calculation is never absolute accurate, values smaller than 1e-12 are treated as 0. Thus, when comparing values, differences smaller than that evaluate to equality.
- A broad subset of the MDES entities has a UUID as attribute. In general, these objects must only be used once in the file and may not be referenced and thus reused. If one copies an element, a new UUID must be generated. Connectors are the only entity that may be referenced. Referencing a connector is done using the ConnectorReference entity as follows:

```
<ConnectorReference ref_uuid="ffd173a1-403f-4b4d-acd6-fc6c5ff2314a"/>
```

- Since the MDES XML is parsable from top to bottom a connector that may be referenced has to be defined first. Consequently, child connectors should be written as the first children of any element.

In the following section, attributes and children of the different specified XML elements are listed. If not marked otherwise only one child is allowed. Attribute values given in *italic* are sample values. Optional children are marked with ? (question mark). Children that can occur zero or more times are marked with * (asterisk).

3.1 Top Level Element

As mentioned, all entities are grouped below the top-level element MDES.

ElementName	Attributes	Children
MDES	version= " <i>x.x.x</i> " applicationName= " <i>Application</i> " applicationVersion= " <i>v123</i> " writerName= " <i>WriterLibraryName</i> " writerVersion= " <i>writerVersion123</i> "	Library WorkAreaAssignment* MagazineAssignment* CustomAttribute*

Multiple elements optionally contain custom attributes for user extensions. These optional attributes are child elements of their respective parent.

ElementName	Attributes	Children
CustomAttribute	key= " <i>key</i> " value= " <i>value</i> "	-

3.2 Library

The library is used as the location where every item is stored that is not currently used within the context of the machine as the setup or tool. Thus, it can save entities for later use. The library shares the same properties with the folder element. The library must contain as its only child a single folder acting as root folder. A folder may contain other folders or items.

ElementName	Attributes	Children
Library/Folder	name= " <i>FolderName</i> " uuid= " <i>42944e85-3972-4cb2-bdb1-ec9cf81194b8</i> "	AdaptiveItem* Fixture* ModelCuttingTool* ParametricCuttingTool* ParametricCuttingInsert* ModelCuttingInsert* Stock* Tool* Setup* ToolAssembly* SetupAssembly* ConstrainedToolComponent* ConstrainedSetupComponent* Folder* CustomAttribute*

3.3 Work Area Assignment

In a Work Area Assignment, the description of the setup side of a machine is placed. Since there may be multiple logical sections of a machine (e.g., a loading station, a machining area), multiple Work Area Assignments may be defined in one MDES file.

ElementName	Attributes	Children
WorkAreaAssignment	name= " <i>WorkAreaDisplayName</i> " uuid= " <i>62f7f57b-8eb5-4416-936b-5bd4945b65b7</i> " workarea_name= " <i>Example</i> "	SetupMounting* CustomAttribute*

3.4 Magazine Assignment

In a Magazine Assignment, the description of the tool side of a machine is placed. Since there may be multiple independent areas to handle tools, multiple Magazine Assignments may be defined in one MDES file.

ElementName	Attributes	Children
MagazineAssignment	name= " <i>MagazineDisplayName</i> " uuid= " <i>62f7f57b-8eb5-4416-936b-5bd4945b65b7</i> " magazine_name= " <i>Example</i> "	ToolMounting* CustomAttribute*

3.5 Mountings and Mountables

Mountings link the information where a Tool or Setup is mounted inside the machine. The mount stations are referring to an entity inside an external machine model via the string given in the respective mounting.

ElementName	Attributes	Children
ToolMounting	name= " <i>ToolMountingName</i> " uuid= " <i>62f7f57b-8eb5-4416-936b-5bd4945b65b7</i> " is_active= " <i>true</i> " station_name= " <i>station</i> "	Tool CustomAttribute*
SetupMounting	name= " <i>SetupMountingName</i> " uuid= " <i>62f7f57b-8eb5-4416-936b-5bd4945b65b7</i> " is_active= " <i>true</i> " station_name= " <i>station</i> "	Setup CustomAttribute*
Tool	name= " <i>ToolName</i> " uuid= " <i>90320e9b-f5b4-49a3-94a8-1221de1f6693</i> " tool_number= " <i>5</i> "	ConstrainedToolComponent* CustomAttribute*
Setup	name= " <i>SetupName</i> " uuid= " <i>62f7f57b-8eb5-4416-936b-5bd4945b65b7</i> "	ConstrainedSetupComponent* CustomAttribute*

3.6 Constrained Components

To position different components in a machine context with respect to each other and with respect to defined points in the machine, constrained components shall be used. In this context, a constraint consists of a Reference Point, which refers to a Connector of one of its child Components, and a transform. The transform describes a coordinate system in relation to the coordinate system of the mount station (defined separately in a machine model). The purpose of the constraint is to describe how a Component should be positioned and oriented in the mount station coordinate system so that its reference point coincides with the transform of the Constraint. Additionally, a work offset can be specified to indicate that the transform value should be taken from a work offset given by a connected, real or virtual CNC machine. The binding mode specifies whether the value was taken from the work offset once or whether it should automatically update if possible.

If a Constraint is specified on a Reference Point of the direct child of the Constrained Component, the transformation resulting from applying a Constraint should be stored in the transform of the Constrained Component to reflect the current positioning.

ElementName	Attributes	Children
ConstrainedToolComponent	name= " <i>ConstrainedToolComponentName</i> " uuid= " <i>62f7f57b-8eb5-4416-936b-5bd4945b65b7</i> " transform= " <i>none</i> "	one of [AdaptiveItem, ToolAssembly, ParametricCuttingTool, ModelCuttingTool, ParametricCuttingInsert, ModelCuttingInsert] Constraint* (1) CustomAttribute*
ConstrainedSetupComponent	name= " <i>ConstrainedSetupComponentName</i> " uuid= " <i>62f7f57b-8eb5-4416-936b-5bd4945b65b7</i> " transform= " <i>none</i> "	one of [Stock, Fixture, SetupAssembly], Constraint* (1) CustomAttribute*

ElementName	Attributes	Children
Constraint	binding_mode="Set" transform="translate(10mm, -8mm, 5mm)" work_offset="G54"	ConnectorReference? (2) LinearAxisOffsetValue* RotationAxisOffsetValue*
LinearAxisOffsetValue	name="axisname" value="4.8mm"	-
RotationAxisOffsetValue	name="axisname" value="-1.4deg"	-
ConnectorReference	ref_uuid= "62f7f57b-8eb5-4416-936b-5bd4945b65b7"	

- 1) The first Constraint must appear after the Component. This guarantees that all connectors referenced inside constraints are already read when parsing from top to bottom.
- 2) The ConnectorReference must refer to an existing connector contained in an element within the Constrained-Component to which the Constraint is applied.

3.7 Assembly Definition

The basic types on Tool (AdaptiveItem, ModelCuttingTool, ParametricCuttingTool) as well as on Setup (Fixture, Stock) side may be assembled into higher constructs in Assemblies. These elements are referred to as components. Assemblies themselves are also components to achieve the possibility of recursive constructs. To achieve a universal placement of the sub elements a tree structure is established for the assemblies. Such trees consist of Nodes encapsulating a component. In an Assembly, multiple root Nodes can be held. Each Node in turn then establishes Connections to its children. To reference different geometric positions on each component, Connectors are used. In a Node, the Connector of the contained Component is specified which is used for the Connection to the parent. Within a Connection, the Connector of the Component from the parent Node is specified, which is used for the connection to the child.

To allow an additional transformation between the Components in a Connection without having to adjust their Connectors, a transform can be specified for the child Node. This transform is expressed in the parent connector's coordinate system and is applied between the parent connector transform and the child connector transform — it is not a transform of the child component's own geometry. In case Constraints are used to only position a subtree of an Assembly, the transformation resulting from applying a Constraint should be stored in the transform of this Node to reflect the current relative positioning.

ElementName	Attributes	Children
ToolAssembly	name="ToolAssemblyName" uuid="90320e9b-f5b4-49a3-94a8-1221de1f6693" manufacturer="Manufacturer" custom_id="id" sister_id="id" ident_number="IdentNumber" hand="Right" nc_tool_number="2" (deprecated, use nc_tool_id) nc_tool_id="toolID"	Connector* ToolNode* CustomAttribute*
SetupAssembly	name="SetupAssemblyName" uuid="90320e9b-f5b4-49a3-94a8-1221de1f6693" manufacturer="Manufacturer" ident_number="IdentNumber"	Connector* SetupNode* CustomAttribute*

ElementName	Attributes	Children
ToolNode	transform= " <i>none</i> "	One of [AdaptiveItem, ToolAssembly, ParametricCuttingTool, ModelCuttingTool, ParametricCuttingInsert, ModelCuttingInsert] Connection* (1) ConnectorReference? (1)
SetupNode	transform= " <i>none</i> "	One of [Fixture, Stock, SetupAssembly] Connection* (1) ConnectorReference? (1)
Connection	-	ConnectorReference One of [ToolNode, SetupNode]
Connector	name= " <i>ConnectorName</i> " uuid= " <i>baa3c8cf-8c25-40b7-8cbb-2ac6d4c326d6</i> " transform= " <i>none</i> " origin= " <i>NegativeExtentZ</i> " direction= " <i>WorkpieceSide</i> "	CustomAttribute*

- 1) The Connectors referenced in Connections and by a Node itself must be existing in the Node's child Component. For top to bottom readability, the Component must be the first child.

3.8 Basic Components

On Tool side, the basic components are AdaptiveItem, ModelCuttingTool, ParametricCuttingTool, ModelCuttingInsert, ParametricCuttingInsert. On Setup side, Stock and Fixture components are available.

ElementName	Attributes	Children
AdaptiveItem	name= " <i>AdaptiveItemName</i> " uuid= " <i>90320e9b-f5b4-49a3-94a8-1221de1f6693</i> " manufacturer= " <i>Manufacturer</i> " ident_number= " <i>IdentNumber</i> " hand= " <i>Right</i> " connection_code_machine_side= " <i>HSK06300195</i> " (1) connection_code_workpiece_side= " <i>ZYL20R1875****</i> " (1) nc_tool_number= " <i>2</i> " (deprecated, use nc_tool_id) nc_tool_id= " <i>toolID</i> " stacking_group= " <i>Holder</i> "	Connector* Model CustomAttribute*
ModelCuttingTool	name= " <i>ModelCuttingItemName</i> " uuid= " <i>42944e85-3972-4cb2-bdb1-ec9cf81194b8</i> " manufacturer= " <i>Manufacturer</i> " ident_number= " <i>IdentNumber</i> " flute_count= " <i>1</i> "	Connector* CuttingModel (see Model) NonCuttingModel (see Model) CuttingConditions? (deprecated in favor of ProcessTypes)

ElementName	Attributes	Children
	hand= <i>"Right"</i> rake_angle_axial= <i>"0.2rad"</i> flute_helix_angle= <i>"12deg"</i> process_types = <i>"Brushing"</i> connection_code_machine_side= <i>"ZYL01000115"</i> (1) nc_tool_number= <i>"2"</i> (deprecated, use nc_tool_id) nc_tool_id= <i>"toolID"</i> max_ramp_angle= <i>"30deg"</i>	CustomAttribute*
ParametricCuttingTool	name= <i>"ParametricCuttingItemName"</i> uuid= <i>"42944e85-3972-4cb2-bdb1-ec9cf81194b8"</i> tool_type= <i>"Unsupported"</i> original_type_id= <i>"typeID"</i> manufacturer= <i>"Manufacturer"</i> ident_number= <i>"IdentNumber"</i> flute_count= <i>"1"</i> hand= <i>"Right"</i> rake_angle_axial = <i>"0.2rad"</i> flute_helix_angle= <i>"12deg"</i> process_types = <i>"Milling", "Turning"</i> connection_code_machine_side= <i>"ZYL01000115"</i> (1) nc_tool_number= <i>"2"</i> (deprecated, use nc_tool_id) nc_tool_id= <i>"toolID"</i> max_ramp_angle= <i>"30deg"</i>	Connector* ToolParameterSet CuttingConditions? (deprecated in favor of ProcessTypes) CustomAttribute* Material?
ModelCuttingInsert	name= <i>"ModelCuttingItemName"</i> uuid= <i>"42944e85-3972-4cb2-bdb1-ec9cf81194b8"</i> manufacturer= <i>"Manufacturer"</i> ident_number= <i>"IdentNumber"</i> insert_index_count= <i>"2"</i> process_types = <i>"Turning"</i> hand= <i>"Right"</i> connection_code_machine_side= <i>"ZYL01000115"</i> (1) nc_tool_number= <i>"2"</i> (deprecated, use nc_tool_id) nc_tool_id= <i>"toolID"</i>	Connector* CuttingModel (see Model) NonCuttingModel (see Model) CuttingConditions? (deprecated in favor of ProcessTypes) CustomAttribute*
ParametricCuttingInsert	name= <i>"CuttingInsertName"</i> uuid= <i>"42944e85-3972-4cb2-bdb1-ec9cf81194b8"</i> insert_type= <i>"Unsupported"</i> original_type_id= <i>"typeID"</i> manufacturer= <i>"Manufacturer"</i> ident_number= <i>"IdentNumber"</i> insert_index_count= <i>"2"</i> process_types = <i>"Turning"</i> hand= <i>"Right"</i> connection_code_machine_side= <i>"ZYL01000115"</i> (1) nc_tool_number= <i>"2"</i> (deprecated, use nc_tool_id)	Connector* InsertParameterSet CuttingConditions? (deprecated in favor of ProcessTypes) CustomAttribute* Material?

ElementName	Attributes	Children
	nc_tool_id= " <i>toolID</i> "	
Stock	name= " <i>StockName</i> " uuid= " <i>90320e9b-f5b4-49a3-94a8-1221de1f6693</i> " manufacturer= " <i>Manufacturer</i> " ident_number= " <i>IdentNumber</i> "	Connector* Model Target (see Model) CustomAttribute*
Fixture	name= " <i>FixtureName</i> " uuid= " <i>90320e9b-f5b4-49a3-94a8-1221de1f6693</i> " manufacturer= " <i>Manufacturer</i> " ident_number= " <i>IdentNumber</i> "	Connector* Model CustomAttribute*

- 1) We encourage the use of a connection_code_machine_side and a connection_code_workpiece side as specified by DIN4000-95 like HSK06300195 or ZYL01000115 or as specified by ISO13399-60 like HSK07C0630\$\$\$\$ or ZYL01G1000h\$06.

The CuttingConditions of CuttingTools have been deprecated in favor of ProcessTypes:

ElementName	Attributes	Children
CuttingConditions	none_spinning= " <i>false</i> " stock_spinning= " <i>false</i> " tool_spinning= " <i>true</i> " both_spinning= " <i>false</i> " lathe_drilling= " <i>false</i> "	-

The legacy conversion to the ProcessTypes upon reading is performed as follows:

- none_spinning -> Probing
- stock_spinning -> Turning
- tool_spinning -> Milling
- both_spinning -> MillTurning
- lathe_drilling -> LatheDrilling

For the geometric description of the basic components, there are two options available:

- Parametric description for CuttingTools and CuttingInserts
- Model based descriptions for CuttingTools, Fixtures and Stocks

ElementName	Attributes	Children
ToolParameterSet	-	ToolParameterData*
ToolParameterData	parameter= " <i>CuttingDiameter</i> " value= " <i>-100mm</i> " sourceDescription= " <i>description</i> "	-
InsertParameterSet	-	InsertParameterData*
InsertParameterData	insert_parameter= " <i>InsertWidth</i> " value= " <i>-100mm</i> " sourceDescription= " <i>description</i> "	-
Model	transform= " <i>none</i> "	One of [EmptyGeometry, Box, Cylinder, Tube, Sphere, Capsule, Torus, Ellipsoid, MeshGeometry,

ElementName	Attributes	Children
		NURBSGeometry, RevolvedGeometry, ExtrudedGeometry] Material CustomAttribute*
Material	color="138,148,158,255" (1) material_system="AISI" material_code="1040" hardness_system="HB" hardness_value="4"	CustomAttribute*

- 1) The values of the color are given as four floats in the range of [0, 255] for the values RGBA (red, green, blue, alpha).

3.9 Geometries

As geometric entities the options offered by MDES are: EmptyGeometry, Box, Cylinder, Tube, Sphere, Capsule, Torus, Ellipsoid, MeshGeometry, NURBSGeometry, RevolvedGeometry and ExtrudedGeometry. As unit options after numbers mm (millimetre), in (inch), rad (radian) and deg (degree) are allowed (° is deprecated as of version 3.0.0).

The following recommendations apply to the primitive geometry types to achieve sensible, non-degenerate shapes:

- **Box:** Each component of `min` should be strictly less than the corresponding component of `max`.
- **Cylinder:** `radius` and `height` should be positive. `axis` should be a non-zero vector.
- **Tube:** `inner_radius` and `outer_radius` should both be positive, and `inner_radius` should be strictly less than `outer_radius`. `height` should be positive. `axis` should be a non-zero vector.
- **Sphere:** `radius` should be positive. `segment_start_fraction` and `segment_end_fraction` should both lie in [0, 1], and `segment_start_fraction` should be strictly less than `segment_end_fraction`. `axis` should be a non-zero vector.
- **Capsule:** `radius` should be positive. `cylinder_height` should be non-negative. `axis` should be a non-zero vector.
- **Torus:** `torus_radius` and `tube_radius` should both be positive. `tube_radius` should be less than or equal to `torus_radius` to avoid a self-intersecting surface. `axis` should be a non-zero vector.
- **Ellipsoid:** `semi_axis_x`, `semi_axis_y`, and `semi_axis_z` should all be positive.

Note that MDES places no restrictions on the values that may be saved. Behavior when an application attempts to generate a geometry from values outside these recommendations is implementation-defined — implementations are free to handle such cases as they see fit (e.g., by producing a degenerate shape or raising an error).

Geometries contain attributes and have children as following:

ElementName	Attributes	Children
EmptyGeometry	-	-
Box	min="-10mm, -10mm, 0mm" max="10mm, 10mm, 10mm"	-
Cylinder	start_point="0mm, 0mm, 0mm" axis="0, 0, 1" height="50mm" radius="10mm"	-
Tube	start_point="0mm, 0mm, 0mm" axis="0, 0, 1"	-

ElementName	Attributes	Children
	height="50mm" inner_radius="7mm" outer_radius="10mm"	
Sphere	center_point="0mm, 0mm, 0mm" radius="10mm" segment_start_fraction="0" (1) segment_end_fraction="1" (1) axis="0, 0, 1" (1)	-
Capsule	start_point="0mm, 0mm, 0mm" (2) radius="10mm" cylinder_height="8mm" axis="0, 0, 1"	-
Torus	center_point="0mm, 0mm, 0mm" axis="0, 0, 1" torus_radius="10mm" tube_radius="1mm"	-
Ellipsoid	center_point="0mm, 0mm, 0mm" semi_axis_x="10mm" semi_axis_y="10mm" semi_axis_z="10mm"	-
MeshGeometry	length_unit="millimetre" mesh_folder_index="1" (3) original_path="fixture.stl"	-
NURBSGeometry	length_unit="millimetre" nurbs_folder_index="1" (4) original_path="fixture.stp"	-
RevolvedGeometry	length_unit="millimetre"	Contour (7)
ExtrudedGeometry	length_unit="millimetre" extrusion_vector="0,0,1" (5) thickness="1.0" (6) construction_plane="1,1,0" draft_angle="12deg"	Contour* (7)

- 1) The segment_start_fraction and segment_end_fraction attributes can be used to define a spherical segment. Both values define a fraction of the sphere diameter along the given axis, and default to 0 and 1 respectively. Thus, the default is a complete sphere, whereas e.g. segment_start_fraction=0.5, segment_end_fraction=1 would describe the upper half of a sphere. For the spherical segments additionally the symmetry axis can be specified, which defaults to (0,0,1).
- 2) The start_point refers to the center of the base of the cylinder of the capsule. The two semicircles are added afterwards.
- 3) Next to the XML file, there may be a folder with an equal name as the xml file without the ending. Inside this folder, meshes can be saved as STL files (name convention mesh_0000.stl and consecutive numbering) and may be referenced by its consecutive number in the mesh_folder_index attribute.
- 4) Next to the XML file, there may be a folder with an equal name as the xml file without the ending. Inside this folder, NURBS can be saved as STP files (name convention nurbs_0000.stp and consecutive numbering) and

may be referenced by its consecutive number in the `nurbs_folder_index` attribute.

- 5) The provided vector does not have to be normalized. The length of the vector does not influence the extrusion result.
- 6) The thickness attribute may carry a sign and can be equal to zero. The combination of the thickness' sign and the `extrusion_vector` defines the extrusion direction.
- 7) Contour elements are specified as follows

ElementName	Attributes	Children
Contour	-	Point2D* Arc2D*
Point2D	x= "1" y= "2.2"	-
Arc2D	center= "1,1" end= "1.5,1.5" (1, 2) rotation_direction= "clockwise"	-

Additional remarks:

- 1) An Arc2d always connects the last contour point with its **end**-point. Therefore, a contour must never have Arc2D as its first child.
- 2) If an Arc2D starts and ends at the same point, it defines a full circle.

3.10 Values for attributes

In the following the type Enum specifies an enumerated type, representing a data type for a set of named values. The type Number specifies a positive or zero integer value. Deprecated Enum types have an annotation for their replacement. Process types are displayed as a comma separated list of `process_types`.

Attribute	Type	Example values (for Enums all options given)
version	version number	1.3.15
application_version (optional)	String	v123
application_name (optional)	String	Application
writer_name (optional)	String	WriterLibraryName
writer_version (optional)	String	WriterLibraryVersion123
workarea_name (optional)	String	WorkAreaName
magazine_name (optional)	String	MagazineName
name (optional except on AxisOffsetValues)	String	ElementName
uuid	UUID	62f7f57b-8eb5-4416-936b-5bd4945b65b7
is_active (optional)	Bool	true false
station_name (optional)	String	StationName

Attribute	Type	Example values (for Enums all options given)
tool_number (optional)	Number	5
binding_mode	Enum	Manual Set Bind
transform (optional)	Transformation	Please refer to chapter Transformations for further explanation.
work_offset (optional)	String	G54
value (CustomAttribute)	String	A Value
value	Length/Angle	5mm 4deg
manufacturer (optional)	String	Manufacturer
connection_code_machine_side (optional)	String	HSK06300195
connection_code_workpiece_side (optional)	String	ZYL20R1875****
nc_tool_number (optional) (see remark 1)	Number	2
nc_tool_id (optional)	String	ToolId
stacking_group (optional)	Enum	Holder Arbor
max_ramp_angle (optional)	Angle	30deg
custom_id (optional)	String	Id
sister_id (optional)	String	Id
flute_count (optional)	Number	1
flute_helix_angle (optional)	Angle	12deg
rake_angle_axial (optional)	Angle	12deg
hand (optional)	Enum	Right Left Neutral
process_types (optional) (see remark 2)	Enum	Brushing Turning Milling MillTurning LatheDrilling Probing Shaping Grooving NoTouch (see remark 3)

Attribute	Type	Example values (for Enums all options given)
origin (optional)	Enum	Zero BoundingBoxCorner_minX_minY_minZ BoundingBoxCorner_minX_minY_maxZ BoundingBoxCorner_minX_maxY_minZ BoundingBoxCorner_minX_maxY_maxZ BoundingBoxCorner_maxX_minY_minZ BoundingBoxCorner_maxX_minY_maxZ BoundingBoxCorner_maxX_maxY_minZ BoundingBoxCorner_maxX_maxY_maxZ PositiveExtentX PositiveExtentY PositiveExtentZ NegativeExtentX NegativeExtentY NegativeExtentZ
direction (optional)	Enum	MachineSide (see 4 for legacy conversion) WorkpieceSide (see 5 for legacy conversion)
ident_number (optional)	String	IdentNumber
tool_type	Enum	AngularEndMill BallNosedEndMill CentreCuttingEndMill DieEndMill DovetailEndMill DrillingThreadWhirler NonCentreCuttingEndMill ThreadEndMill ThreadEndMillWithDrillingPart ThreeDProbe TSlotEndMill TwistDrill SpotDrill CounterBoreDrill ThreadMillSingleForm CenterDrill ConcaveRoundedProfileEndMill CuttingStylus ProbeWithStraightShank StepDrill TaperedCountersinkingDrill LollipopMill CylindricalReamer ThreadCuttingTapWithShank BarrelMill CoreDrill Unsupported
insert_type	Enum	ParallelogramInsert TriangularInsert TrigonInsert RoundInsert SquareInsert

Attribute	Type	Example values (for Enums all options given)
		RhombicInsert PentagonalInsert HexagonalInsert OctagonalInsert KiteInsert Unsupported
original_type_id (optional)	String	TypeID
insert_index_count (optional)	Number	3
parameter	Enum	BodyDiameter ChipFluteLength CornerChamferAngle CornerChamferWidth CornerRadius CornerRadius1 CornerRadius2 CountersinkAngle CuttingDiameter CuttingDiameter2 CuttingDiameterFaceContact CuttingDiameterMaximum CuttingDiameterFirstStep CuttingDiameterSecondStep CuttingDiameterThirdStep CuttingDiameterWear DepthOfCutMaximum FunctionalLength HeadChamferLength HeadLength HeadLength1 HeadLength3 LensRadius NeckDiameter NeckDiameter1 NeckDiameter2 NonCuttingAngle NonCuttingCornerRadius NonCuttingDiameter NonCuttingDiameterCorner NonCuttingDiameterFlat NumberOfThread OverallLength PlungeDepthMaximum PointAngle PointLength PremachinedHoleDiameter ProbeDiameter ProbeNeckDiameter ProfileAngle ProfileIncludedAngle ProfileRadius ProtrudingLength RadiusCountersunk

Attribute	Type	Example values (for Enums all options given)
		RL ShankChamferLength ShankDiameter ShankLength StepDiameterLength StepDiameterLengthFirstStep StepDiameterLengthSecondStep StepDiameterLengthThirdStep StepDistanceLength StepIncludedAngle StepIncludedAngleSecondStep StepIncludedAngleThirdStep TapChamferPlugDiameter TapPitch ThreadChamferLength ThreadDiameter ThreadDiameterSize ThreadingLength ThreadStartLength ToolCuttingEdgeAngle UsableLength CoreDiameter ThreadPitch ThreadsPerInch CuttingDiameterDrillingPart InterferenceCuttingDiameter UpperCornerRadius UpperCornerChamferAngle UpperCornerChamferWidth UpperPlungeDepthMaximum UpperNonCuttingDiameterFlat UpperNonCuttingDiameterCorner UpperNonCuttingAngle UpperNonCuttingCornerRadius ProfilePositionAxial
insert_parameter	Enum	InsertWidth InsertLength CuttingEdgeLength CornerRadius CornerRadius1 CornerRadius2 CornerRadius3 InsertIncludedAngle InsertIncludedAngle1 InsertIncludedAngle2 InsertIncludedAngle3 ClearanceAngleMajor InsertThickness InscribedCircleDiameter MirrorBaseShape
source_description (optional)	String	SourceDescription

Attribute	Type	Example values (for Enums all options given)
color	Number, Number, Number, Number (RGBA values 0 to 255)	138, 148, 158, 255
material_system (optional)	Enum	AISI ANFOR ASTM BTS DIN EN ENMaterialNumber JIS SAE SIS UNI UNS VDI_3323
material_code (optional)	String	MaterialCode
hardness_system (optional)	Enum	HB HRC
hardness_value (optional)	Float	2.1
none_spinning (optional), stock_spinning (optional), tool_spinning (optional), both_spinning (optional), lathe_drilling (optional)	Bool	true false
length_unit	Enum	millimetre inch
min, max, start_point center_point	Length, Length, Length	-10mm, -12mm, 8mm
axis (optional on Sphere), extrusion_vector, construction_plane	Float, Float, Float	0,0,1
height, radius, inner_radius, outer_radius torus_radius tube_radius cylinder_height semi_axis_x semi_axis_y semi_axis_z	Length	7mm

Attribute	Type	Example values (for Enums all options given)
start, end, center,	Float, Float,	2.3, 4.5
x, y, endx, endy, thickness	Float	1.1
segment_start_fraction (optional), segment_end_fraction (optional),	Float	0.1
rotation_direction	Enum	clockwise counterclockwise
draft_angle (optional)	Angle	0.2rad
mesh_folder_index	Number	3
original_path (optional)	String	stock.stl
nurbs_folder_index	Number	3

Additional remarks:

- 1) nc_tool_number is deprecated in favor of nc_tool_id
- 2) The process types list describes those processes a certain tool is suited for. This can be a single one or a combination of multiple types. However, contradicting types must not be combined, since upon combining them the behavior is undefined.
- 3) The process type NoTouch is meant to be used for a tool, that is neither allowed to cut, nor is allowed to touch anything. Thus, e.g. in the use case of collision checking, this tool behaves like a part of the machine. Combination of any process type with NoTouch results in undefined behavior, since it contradicts all other types.
- 4) In versions < 3.0.0 MS was used, XML-Reader must convert to MachineSide.
- 5) In versions < 3.0.0 WS was used, XML-Reader must convert to WorkpieceSide.

3.11 Transformations

Transformation attributes can have the values “none”, “translate”, “rotate” or “eulertranslation”.

3.11.1 Translation

A translation can be defined by using the attribute type “translate”. A “translate” has the three arguments xTranslation, yTranslation, zTranslation. The arguments can be given in the following way translate(xTranslation, yTranslation, zTranslation). All arguments are lengths as previously defined. A valid translate would follow the pattern translate(Length, Length, Length). An example for a valid translate is:

```
translate(18.2in, -3.3in, 5in)
```

Furthermore, there are short forms available for the case of a translation along only one axis: translateX(Length), translateY(Length), translateZ(Length).

3.11.2 Rotation

A rotation can be defined by using the attribute type “rotate”. A “rotate” value has the three arguments rotationAngle, rotationAxis, rotationCenter. The arguments can be given in the following way rotate(rotationAngle, rotationAxis, rotationCenter). The rotationAngle argument is an angle as previously defined. The rotationAxis argument is a number vector and can be entered as (Float, Float, Float). The rotationCenter argument is a point which can be entered as (Length, Length, Length). A valid rotate would follow the pattern rotate(Angle, (Float, Float, Float), (Length, Length, Length)). An example for a valid rotate is:

```
rotate(51deg, (1.0, 1.0, 0.0), (3mm, 15mm, -6.3mm))
```

For the case of the rotation center at (0,0,0), it can be omitted. Thus rotate(Angle, (Float,Float,Float)) denotes a valid rotation. Furthermore there are short forms available for the case of an rotation around the X-, Y- or Z-axis, either with a non-zero or zero rotation-center: rotateX(Angle, (Length, Length, Length)) or rotateX(Angle), rotateY(Angle, (Length, Length, Length)) or rotateY(Angle), rotateZ(Angle, (Length, Length, Length)) or rotateZ(Angle).

3.11.3 Euler Translation

An Euler Translation can be defined by using the attribute type “eulertranslation”. An “eulertranslation” value has the three arguments rotation, order, and translation. The arguments can be given in the following way eulertranslation(rotation, order, translation). The rotation argument consists of three angles which can be entered as (Angle, Angle, Angle). The order argument must be chosen from the Enum values XYZ, YZX, ZXY, XZY, ZYX, YXZ. The translation argument consists of three lengths and can be entered as (Length, Length, Length). Consequently, a valid eulertranslation would follow the pattern eulertranslation((Angle, Angle, Angle), XYZ, (Length, Length, Length)). An example for a valid eulertranslation is:

```
eulertranslation((5deg, 3.78deg, -38deg), XYZ, (-2mm, 5.32mm, 18mm))
```

Example use cases

In this chapter, a selection of specific examples is described to provide further background on the intentions of the creators and inspire the application. The examples chosen are typical scenarios of data exchange happening in manufacturing companies but are in no way complete. The examples are ordered along the process of value creation within a production company, as depicted below.

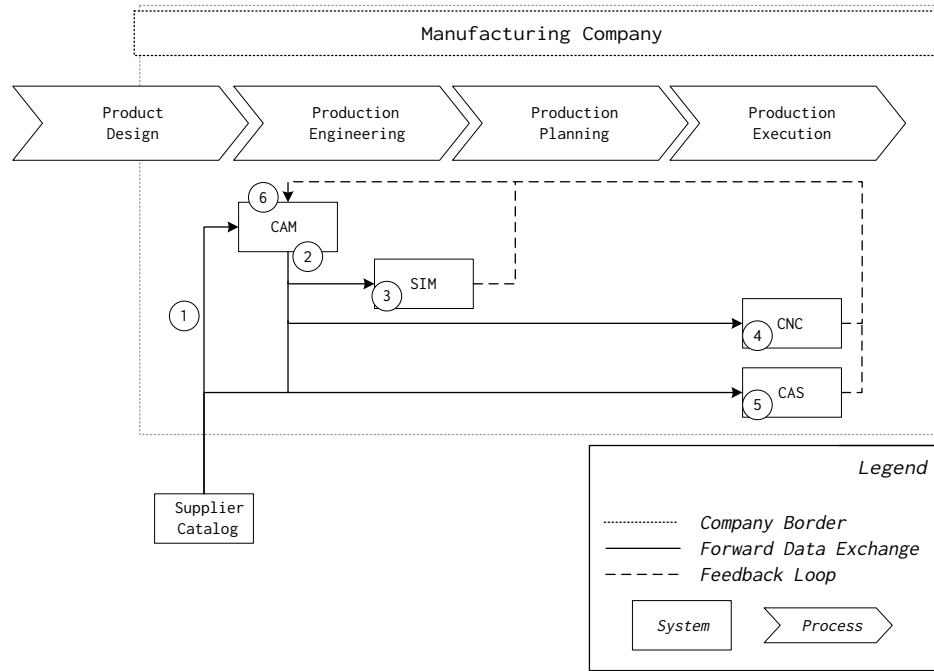


Figure 4.1: Value creation process in a manufacturing company, with associated software systems and data flows. (1) Import of vendor tooling data into a CAM system, (2) Definition of setups and tooling within a CAM system, (3) Import and usage of MDES data in a dedicated offline simulation system, (4) Setup of CNC control tooling information by importing and refining MDES data, (5) Import and usage of MDES data in a dedicated offline simulation system, (6) Re-import of adapted MDES data into a CAM system for fixing errors

Due to the nature of MDES and the background of the creators, the samples are chosen to originate from the production engineering and production execution phase. The samples are mapped to the corresponding chapters found in the following.

4.1 Import of vendor tooling data into a CAM system

To use CAM systems for the definition of manufacturing strategies, such as milling toolpaths, digital descriptions of manufacturing equipment must be available. Specifically, this includes the description of cutting tools. Traditionally, cutting tool data is provided in catalogs by the cutting tool manufacturers and vendors. In recent times, thanks to

initiatives for standardization of cutting tool descriptions (e.g., ISO 13399) and the investments of tool vendors into such offers, vendor data for cutting tools is increasingly available in digital form. This includes parametric descriptions in digital catalogs, provisioning of parametric descriptions via specific file formats or APIs, and provisioning of geometric tool models in native CAD formats or exchange formats such as STEP.

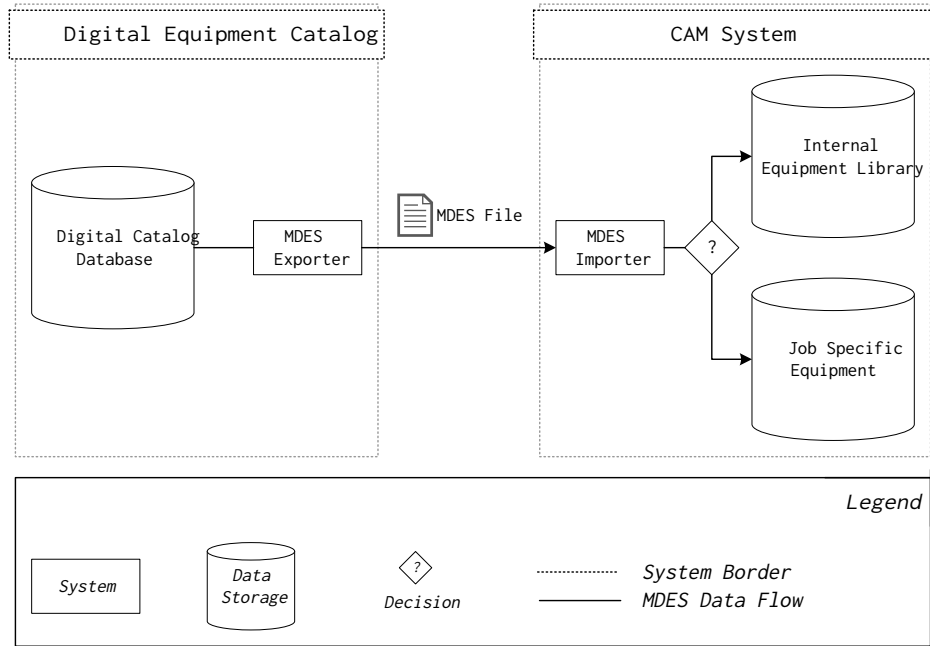


Figure 4.2: MDES based data exchange between equipment suppliers and CAM systems

In this scope, the ISO based cutting tool description of MDES can be used as a standardized import interface for digital representations of cutting tools into CAM systems. Tool vendors or other sources of digitized cutting tool descriptions can choose MDES as an output format for the description of their products. This way, data exchange between cutting tool vendors and CAM systems can be improved. As a result, the user of a CAM system will be able to set up his system for the fulfilment of the primary job, the definition of manufacturing strategies, more efficiently in all CAM systems supporting MDES as an import format and for all tooling suppliers supporting MDES as an export format. During the import step, within the CAM System, the MDES representation of the cutting tool can either be converted into the internal database format of the CAM system for the storage of tools or persisted individually or combined with other tools in the MDES format for the usage within a specific CAM job or in general for future usage in an internal tool library of the CAM system. Because MDES is designed with the specific requirements of toolpath planning in mind, it can include all relevant information for this process step.

4.2 Definition of setups and tooling within a CAM system

Although it is desirable to import vendor data for tooling into CAM systems to minimize overhead work for the user, it is necessary that the user is also able to define tooling himself. While the user might have no desire to define tooling, vendor data might not always be available or special tools must be designed for the fulfilment of a specific manufacturing job. To enable users to define tooling themselves, the CAM system developer must create an input form as a graphical user interface. Using this interface, the user can specify tools by, e.g., setting the parameters for a specific cutting tool type and combining it with models for adaptive items created via a CAD system.

MDES supports this phase by providing a data model for the digital description of cutting tools via their assembly from cutting items, tool items and adaptive items according to ISO 13399. The MDES data model can be used for the storage of user-defined tooling and the graphical user interface for the user input of the tooling information. Utilizing the MDES data model for user-defined tooling allows the consistent handling of both vendor-supplied tool descriptions and user-defined tooling in a single data model. In addition to the description of cutting tools, MDES also provides a structure for defining fixture devices and workpieces and assembling those in setups. This is typically done in CAM systems by utilizing 3D CAD capabilities, such as solid modeling and assemblies. MDES supports this

by providing a structure that allows to combine the 3D CAD components and assemblies with a semantic layer. This layer enables providing additional information beyond the geometry and allows to handle setup elements by their function, instead of a pure geometric handling as a CAD component in the CAM system.

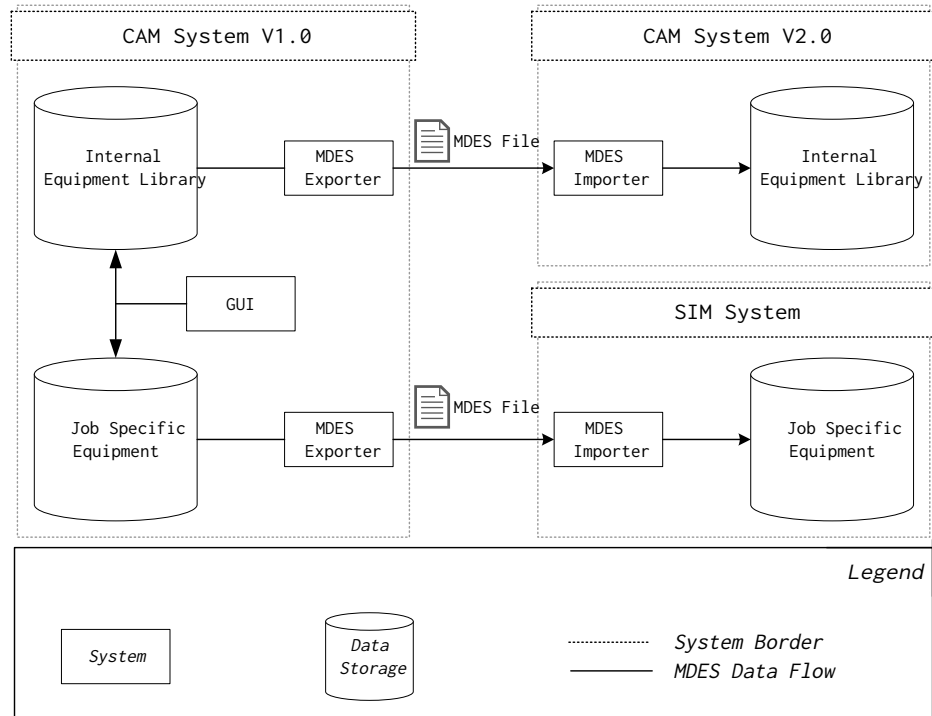


Figure 4.3: MDES based equipment description in CAM systems and export scenarios data migration (above) and data flow to simulation (below)

With tool and setup assemblies available, within the CAM system a machine context can be created. Depending on the specific capabilities of the applied CAM system and the processes within a specific manufacturing engineering department, CAM might happen in machine context or machine independent. If the first option is applied, a machine model is typically available for selection within the CAM system. This machine model should specify mounting points for setups, such as machine tables with fastening interfaces or a workpiece spindle. Additionally, the machine model should specify mounting points for tools, such as the tool spindle, magazine slots on a lathe turret or other magazines in machine tools with automated tool handling. The MDES data model allows to provide mounting contexts by referring to a machine model mount station and defining and storing additional offset data. Similar to the function of MDES for the setup assembly creation, the machine mounting model of MDES enables CAM developers to link 3D CAD components to a functional description with the semantic layer provided by MDES. While the purely functional internal benefits of using MDES for this step might be limited, MDES provides the ability to store the description of components and assemblies together with machine mountings in a single data structure which is especially useful for transferring the equipment definitions made in CAM systems to software systems in later process stages.

For this purpose, an export function can be created in the CAM system that creates an MDES file on a storage location. This could be a local hard drive, a network drive, a Microsoft SharePoint or even a more advanced data backbone in the form of a PDM or PLM system. The export function can be created by again translating data stored in the internal data model of the CAM system into the MDES data model. This step can be omitted if the MDES data model coincides with the internal data model, which further reduces efforts in creating data continuity. For the export, among others, these scenarios could be relevant: - Export of a single piece of equipment, to make a new piece of equipment usable in another system that contains a maintained library of equipment - Export of the complete or subset of equipment used in a specific job, to further process this job in another system (e.g., a dedicated simulation system) - Export of the complete or subset of equipment stored in the CAM internal equipment library, to migrate the data to a newer version of the CAM system

4.3 Import and usage of MDES data in a dedicated offline simulation system

After manufacturing strategies have been defined in CAM, they can be transferred to production execution. Typically, this involves the step of post-processing the CAM internal data format for the manufacturing instructions into a language that is machine readable by the CNC machine tool. This representation shall be utilized during the production execution step. On the CNC machine tool, the manufacturing instructions can then be executed to produce the part as defined in production engineering. Because the manufacturing instructions created during production engineering can contain errors, there is the risk of damage to the production assets during production execution. The potential impact could be production downtimes, repair costs or the total loss of important manufacturing equipment. To limit this risk, simulation systems are used to verify the manufacturing instructions created within CAM. This step of verification can happen on multiple levels of detail (e.g., toolpath-based simulation before post processing, or machine-code-based simulation after post processing). Independent of the level of detail, the verification step can happen integrated within the CAM environment or in a dedicated software system independent of the the CAM environment.

To verify a production job within a dedicated simulation system, the tooling and setup information must be available within that system. Although the same requirements towards user-editability of equipment data that exist in CAM systems are also valid for simulation systems, data continuity between these process steps is especially important as most relevant data has already been created within the CAM system. Similar to the usage in the CAM system, MDES can be used in this context to serve as an import format for the simulation system. It can again be translated into the proprietary internal format chosen by the developer of the simulation system or serve as the internal data model itself. If the latter is chosen, the data transfer between CAM systems that can export MDES datasets and simulations systems becomes especially easy, as no translation step is required.

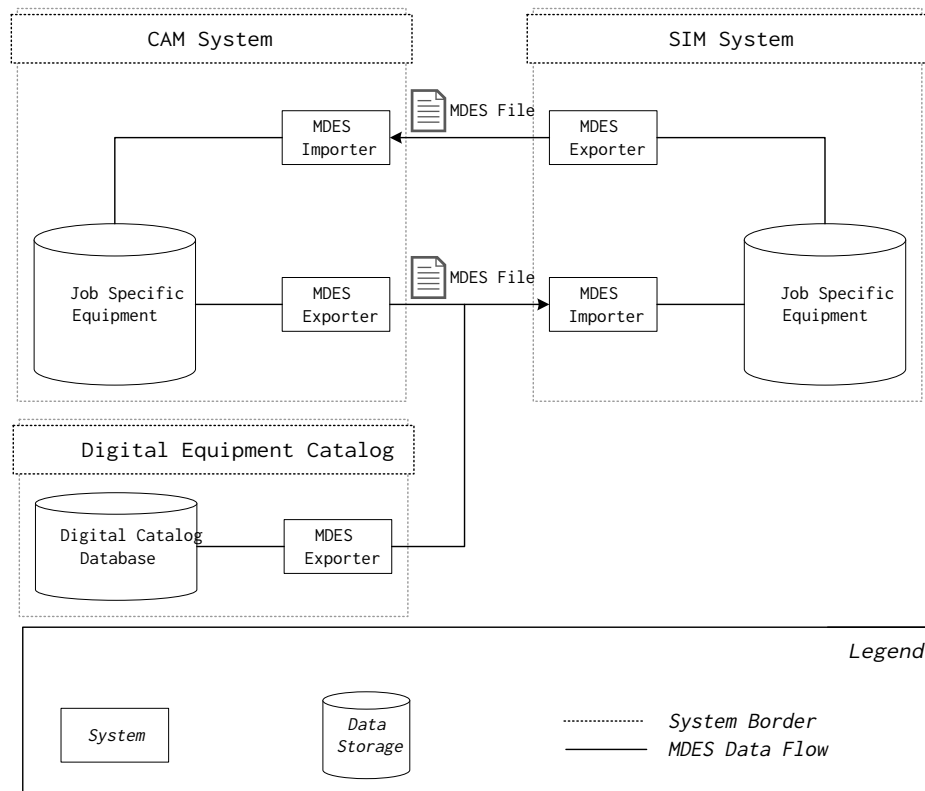


Figure 4.4: MDES applied to enable data exchange between CAM and dedicated simulation systems including feedback loop

4.4 Setup of CNC control tooling information by importing and refining MDES data

To process a production job on a CNC machine tool, manufacturing instructions must be loaded into the CNC control of said machine tool. These manufacturing instructions are then processed by the CNC to control the manufacturing process on the machine tool. During processing, the CNC control again relies on digital description of manufacturing equipment. Specifically, geometrical descriptions of the tools utilized within the manufacturing process must be available within the CNC control for the purpose of e.g., 2D or 3D length and radius compensation.

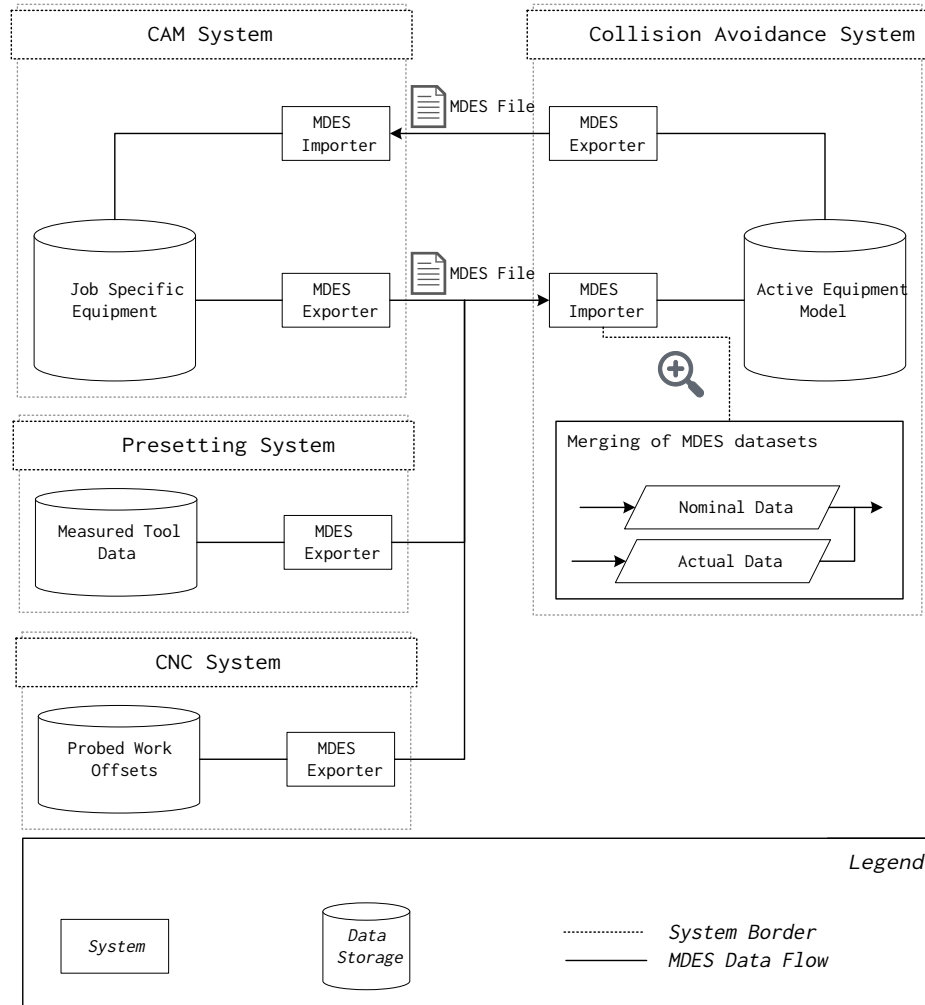


Figure 4.5: Merging of CAM MDES data with presetting MDES data in the CNC for tool geometry compensation with feedback loop

MDES datasets created during production engineering can again serve as an import format to make this information available in the CNC control. Additionally, vendor information might be imported directly to the CNC control using an MDES import interface. Vendor data or data generated within production engineering typically consists of nominal data defined during the design of tooling. To achieve the required quality during production, the actual tool geometry is typically measured to calculate tool geometry compensation values. These values can be used by CNC controls to compensate e.g., tool wear or inaccuracies during the assembly of tools from tool components. The measuring of actual tool geometries can either happen machine-integrated or on special tool presetting machines. MDES datasets can serve as an input format to these machines to provide tool metadata and nominal values for the automation of the measuring process. MDES datasets can be enriched with the actual tool geometry information and compensation values to store them on the CNC control.

The adapted MDES datasets can again be fed back to the production engineering step to create consistency.

Similarly, the setup portion of the manufacturing equipment can deviate from the nominal values defined in production engineering. Inaccuracies in the assembly of the setup and its mounting on the machine can easily cause problems during manufacturing. Typically, measurement and probing tools are used on CNC machine tools to compensate for the offsets on the setup side. Alternatively, geometrically defined setup systems, such as zero-point clamping systems, might be utilized to minimize the need for measuring and probing. If compensation values for the setup side are measured on the CNC machine or on a dedicated setup presetting station, these can be stored within the MDES dataset to be considered during the production execution. Again, for the purpose of data consistency, these compensation values can be fed back into the production engineering step.

4.5 Import and usage of MDES data in an online collision avoidance system

Although the usage of offline simulation systems greatly reduces the risks of executing new manufacturing instructions on CNC machinery, the remaining risk can justify the deployment of online collision avoidance systems on the machine tool. Such systems run a simulation during the production execution in parallel to the machine movements. Because the simulation happens in an accelerated way or slightly in advance of the machine movements, errors that could cause severe damage to equipment and potential production downtime can be detected before they occur in reality. If an error is detected, the machine can be stopped before the error causes damage. To protect the manufacturing equipment used within the machine space, a digital description of the manufacturing equipment must be available on the machine.

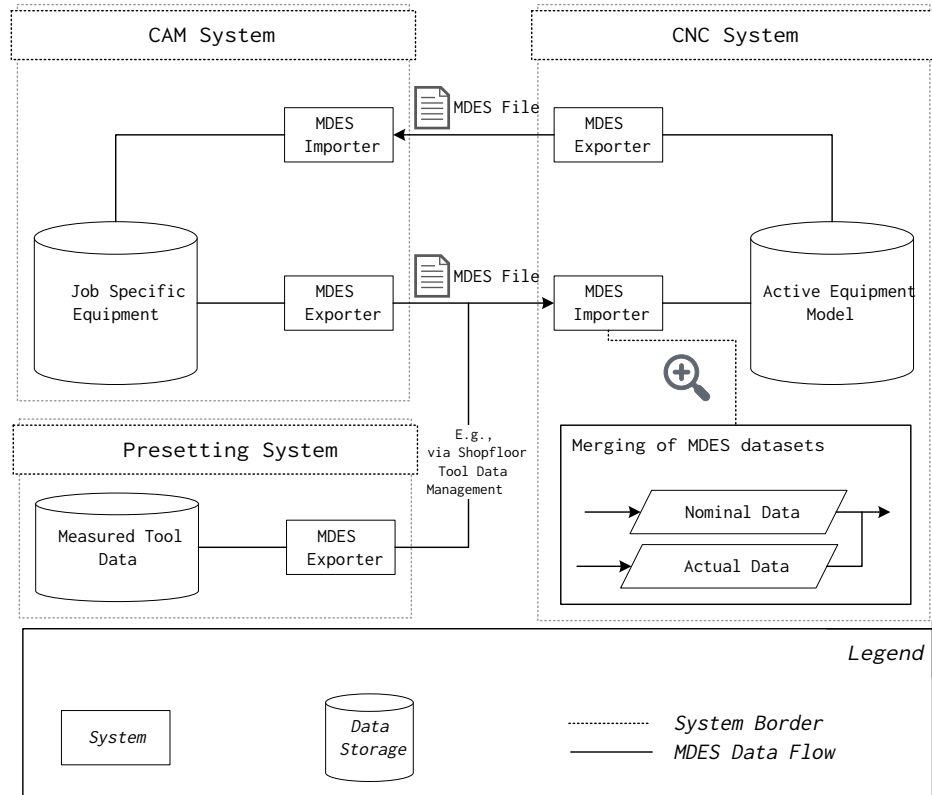


Figure 4.6: MDES usage to provide a Collision Avoidance System with actual tool and setup data, including feedback loop

MDES can be used to import equipment datasets created in work preparation into a collision avoidance system. Additionally, vendor data can be imported into the collision avoidance system via an MDES interface. Similarly, to the usage of MDES for the description of tool geometries for the purpose of geometric compensation in the CNC control, the collision avoidance system requires actual data to reduce the risk of collisions as much as possible. With MDES, nominal data from production engineering can be imported into the collision avoidance system and either updated manually to fit actual data or updated with the results of on-machine measuring or measuring on

presetting systems. MDES can be used as the internal data model for the storage and usage of digital descriptions of manufacturing equipment within a collision avoidance system, which reduces the need for converting data back and forth during import and export of MDES datasets. MDES datasets representing actual values can be exported from a collision avoidance system to feed back into the production engineering step for the purpose of data consistency.

4.6 Re-import of adapted MDES data into a CAM system for fixing errors

Although a collision avoidance system can protect the machine against the consequences of collisions, it will stop the machine and interrupt production execution. To resume operation, the underlying error must be fixed. Depending on the type of error and the specific situation in the manufacturing company this can happen either directly at the machine, or by iterating through the production-engineering step and department. In the latter case, it is particularly important that up-to-date digital descriptions of the equipment and mounting state are available in production engineering so that errors can be reproduced, debugged, and solved.

MDES allows the export of nominal equipment data from production engineering or equipment vendors to production execution, but also facilitates the flow of information in the reverse direction. As described in the previous use cases, MDES datasets can be updated on the shop floor based on measurement results or because plans were changed due to equipment not being available for production execution. From the system in production execution, MDES datasets can be exported reflecting the actual state of equipment and re-imported in production engineering, e.g., in CAM systems. This way, the calculation of manufacturing strategies, such as milling toolpaths, can be started again with an up-to-date data model. This feedback loop speeds up the identification and solution of errors that might have occurred in the production engineering step.

Parametric Tool Description

For all following tool descriptions, the parameter DCONMS (ShankDiameter) is used to describe the tools diameter at the machine side of the tool. Depending on the exact tool, other common names for this parameter are DMM or ‘Connection diameter machine side’.

For some tools, certain combinations of parameters can be given, resulting in an overspecified geometry. For those cases, it is mandatory, that the values describe the same geometry.

5.1 Solid Endmills (Compatible with ISO 13399-303)

In the following subchapters parametric tool models for solid endmills are defined.

With respect to the symbols for specific parameters used in the following a few rules regarding evaluation of the parameters as well as default values are used:

1. If RE is given in addition to KCH and CHW, RE is applied to the bottom corner of the chamfer.
2. LHN and LSN are zero by default.
3. If both NON-DCF and NON-DCC are given, NON-DCF will be applied.
4. If neither NON-DCF nor NON-DCC is given, 50% of DC is used as NON-DCF.
5. If AZ is not given, 1% of DC but at least 0.1mm is used.
6. If LH is not given, APMX is used as value.
7. If LS is not given, it is computed as $OAL - LH - LHN - LSN$.
8. Either none or both of KCH and CHW should be given, if applicable. This may be enforced in a future version.

5.1.1 Non-Centre Cutting End Mill

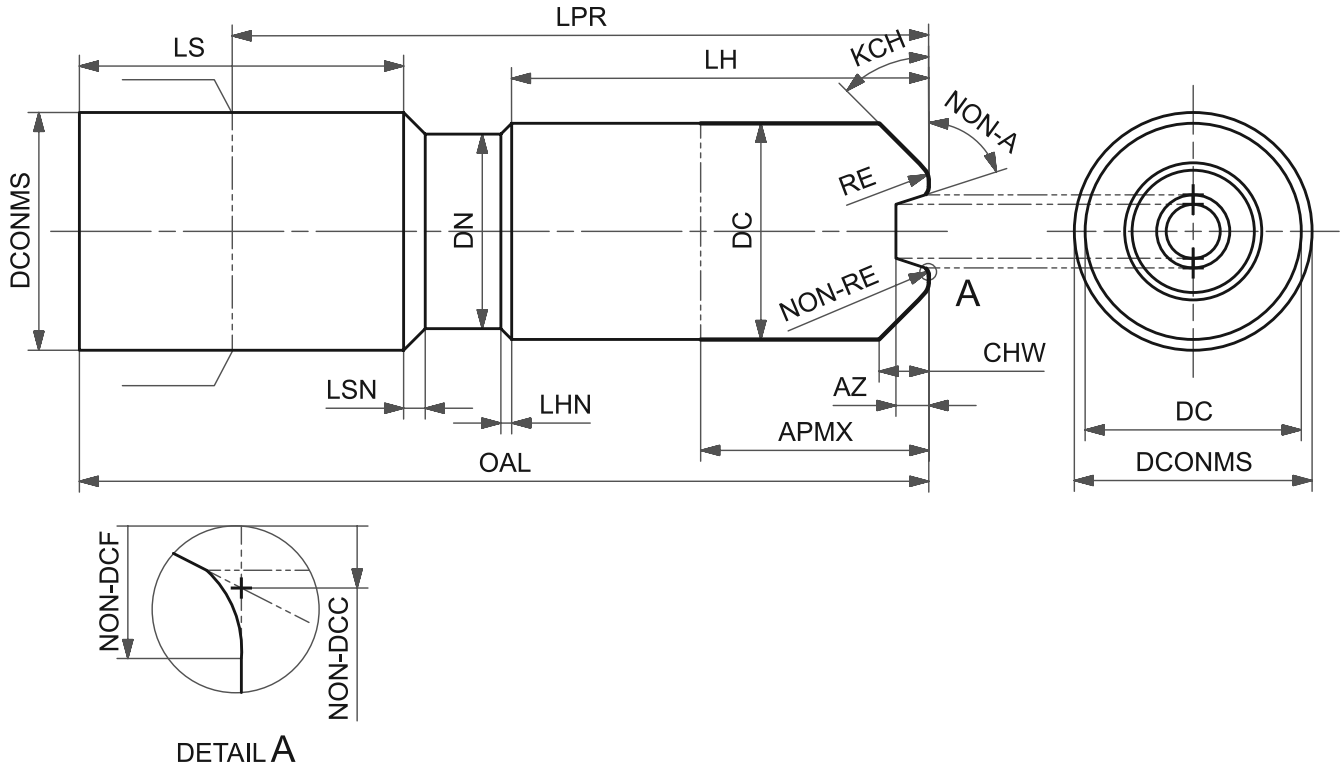


Figure 5.1: Depiction of a Non-Centre Cutting End Mill

Symbol	Parameter Name	Type	Requirements
DC	CuttingDiameter	Length	Required
APMX	DepthOfCutMaximum	Length	Required
OAL	OverallLength	Length	Required
LPR	ProtrudingLength	Length	Optional
LS	ShankLength	Length	Optional
LH	HeadLength	Length	Optional
LHN	HeadChamferLength	Length	Optional
LSN	ShankChamferLength	Length	Optional
DN	NeckDiameter	Length	Optional
DCNMS	ShankDiameter	Length	Optional
RE	CornerRadius	Length	Optional
KCH	CornerChamferAngle	Angle	Optional
CHW	CornerChamferWidth	Length	Optional
AZ	PlungeDepthMaximum	Length	Optional
NON-DCF	NonCuttingDiameterFlat	Length	Optional
NON-DCC	NonCuttingDiameterCorner	Length	Optional
NON-A	NonCuttingAngle	Angle	Optional
NON-RE	NonCuttingCornerRadius	Length	Optional

5.1.2 Centre Cutting End Mill

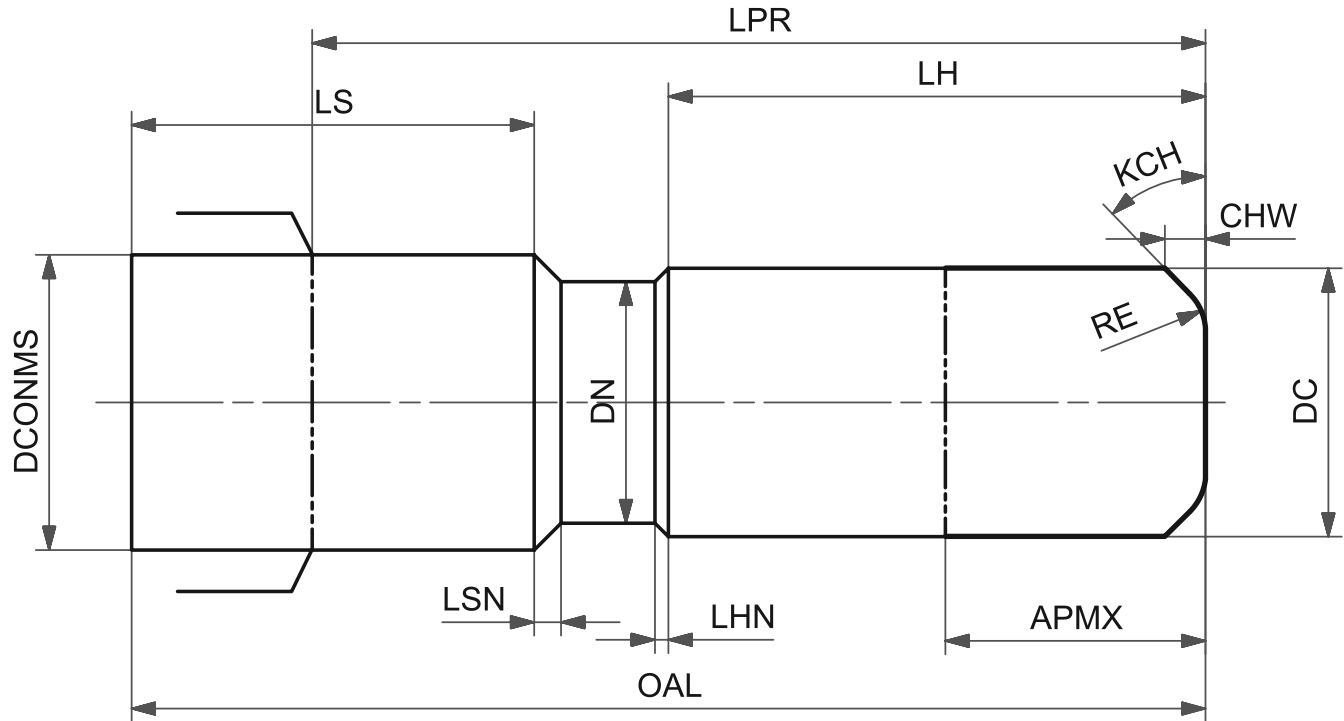


Figure 5.2: Depiction of a Centre Cutting End Mill

Symbol	Parameter Name	Type	Requirements
DC	CuttingDiameter	Length	Required
APMX	DepthOfCutMaximum	Length	Required
OAL	OverallLength	Length	Required
LPR	ProtrudingLength	Length	Optional
LS	ShankLength	Length	Optional
LH	HeadLength	Length	Optional
LHN	HeadChamferLength	Length	Optional
LSN	ShankChamferLength	Length	Optional
DN	NeckDiameter	Length	Optional
DCONMS	ShankDiameter	Length	Optional
RE	CornerRadius	Length	Optional
KCH	CornerChamferAngle	Angle	Optional
CHW	CornerChamferWidth	Length	Optional

5.1.3 Angular End Mill

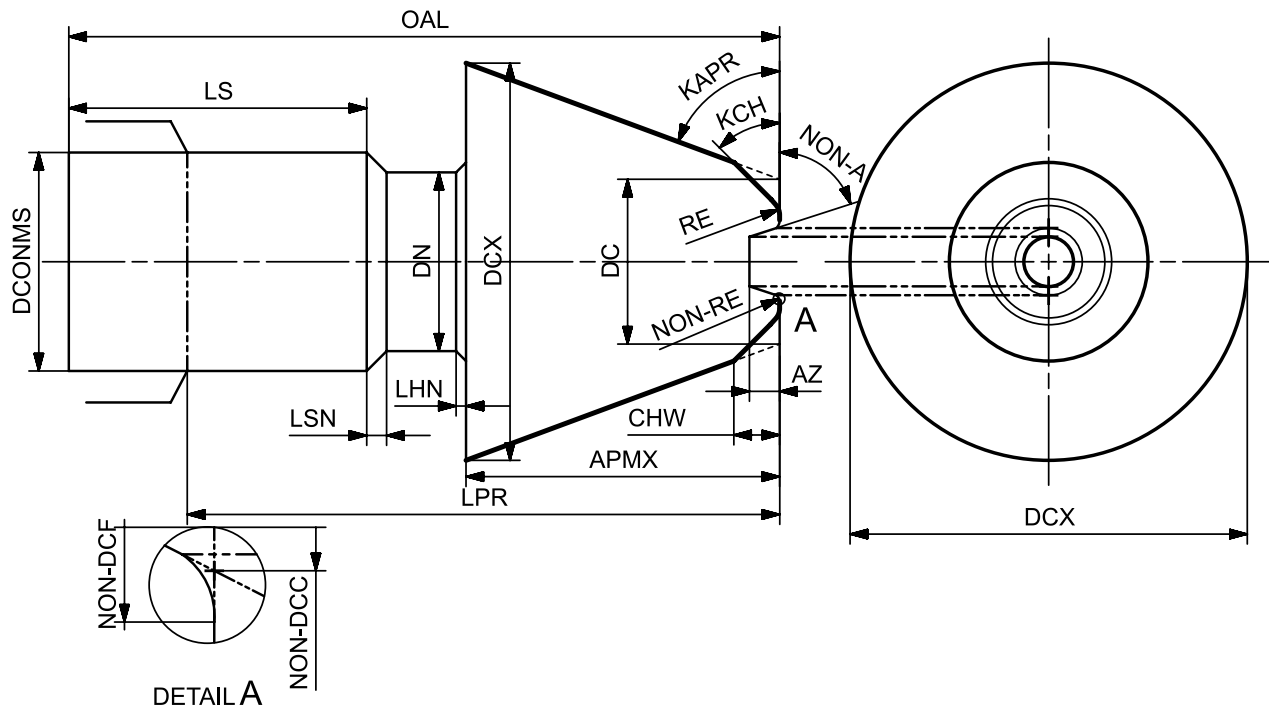


Figure 5.3: Depiction of an Angular End Mill

Additional remarks:

1. If both KAPR and DCX are given, KAPR will be applied.

Symbol	Parameter Name	Type	Requirements
DC	CuttingDiameter	Length	Required
APMX	DepthOfCutMaximum	Length	Required
OAL	OverallLength	Length	Required
DCX	CuttingDiameterMaximum	Length	1 of 2 Non-Optional with KAPR
KAPR	ToolCuttingEdgeAngle	Angle	1 of 2 Non-Optional with DCX
LPR	ProtrudingLength	Length	Optional
LS	ShankLength	Length	Optional
LSN	ShankChamferLength	Length	Optional
LHN	HeadChamferLength	Length	Optional
DN	NeckDiameter	Length	Optional
DCONMS	ShankDiameter	Length	Optional
RE	CornerRadius	Length	Optional
KCH	CornerChamferAngle	Angle	Optional
CHW	CornerChamferWidth	Length	Optional
AZ	PlungeDepthMaximum	Length	Optional
NON-DCF	NonCuttingDiameter Flat	Length	Optional
NON-DCC	NonCuttingDiameter Corner	Length	Optional
NON-A	NonCuttingAngle	Angle	Optional
NON-RE	NonCuttingCornerRadius	Length	Optional

5.1.4 Dovetail End Mill

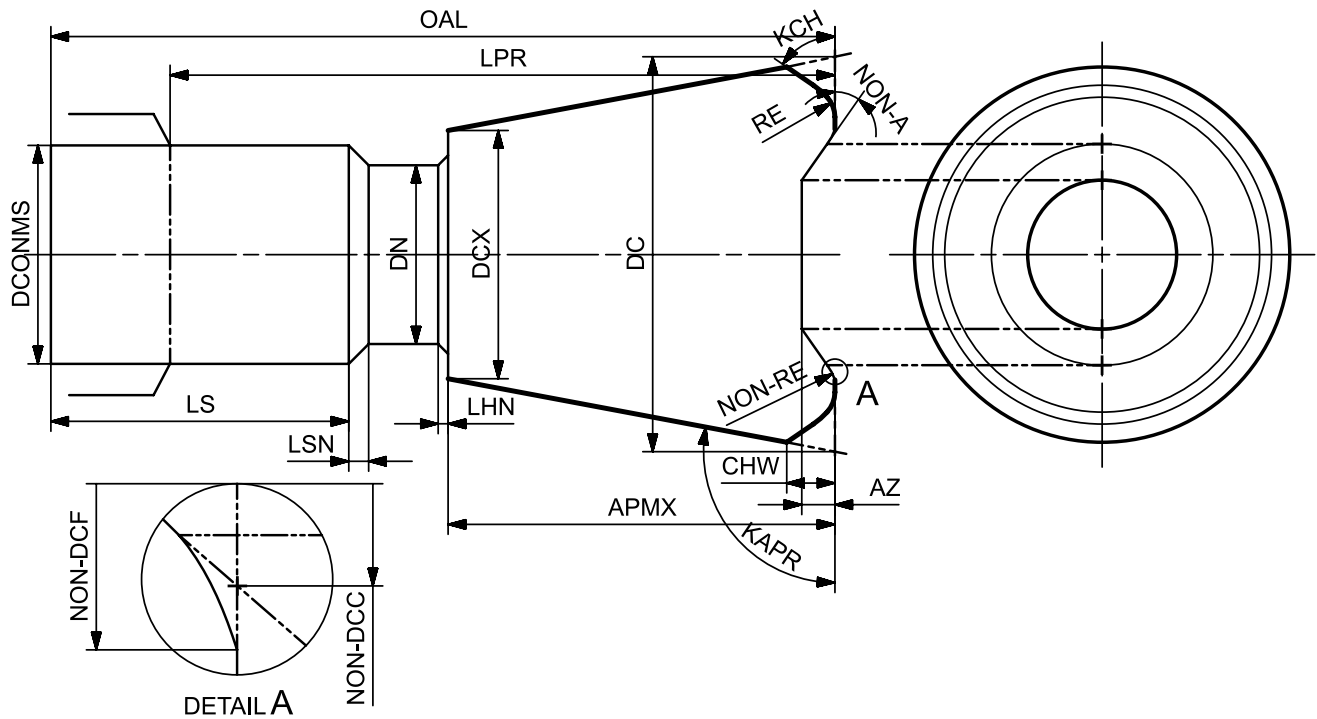


Figure 5.4: Depiction of a Dovetail End Mill

Symbol	Parameter Name	Type	Requirements
DC	CuttingDiameter	Length	Required
APMX	DepthOfCutMaximum	Length	Required
OAL	OverallLength	Length	Required
DCX	CuttingDiameterMaximum	Length	1 of 2 Non-Optional with KAPR
KAPR	ToolCuttingEdgeAngle	Angle	1 of 2 Non-Optional with DCX
LPR	ProtrudingLength	Length	Optional
LS	ShankLength	Length	Optional
LHN	HeadChamferLength	Length	Optional
LSN	ShankChamferLength	Length	Optional
DN	NeckDiameter	Length	Optional
DCONMS	ShankDiameter	Length	Optional
RE	CornerRadius	Length	Optional
KCH	CornerChamferAngle	Angle	Optional
CHW	CornerChamferWidth	Length	Optional
AZ	PlungeDepthMaximum	Length	Optional
NON-DCF	NonCuttingDiameter Flat	Length	Optional
NON-DCC	NonCuttingDiameter Corner	Length	Optional
NON-A	NonCuttingAngle	Angle	Optional
NON-RE	NonCuttingCornerRadius	Length	Optional

5.1.5 T-Slot End Mill

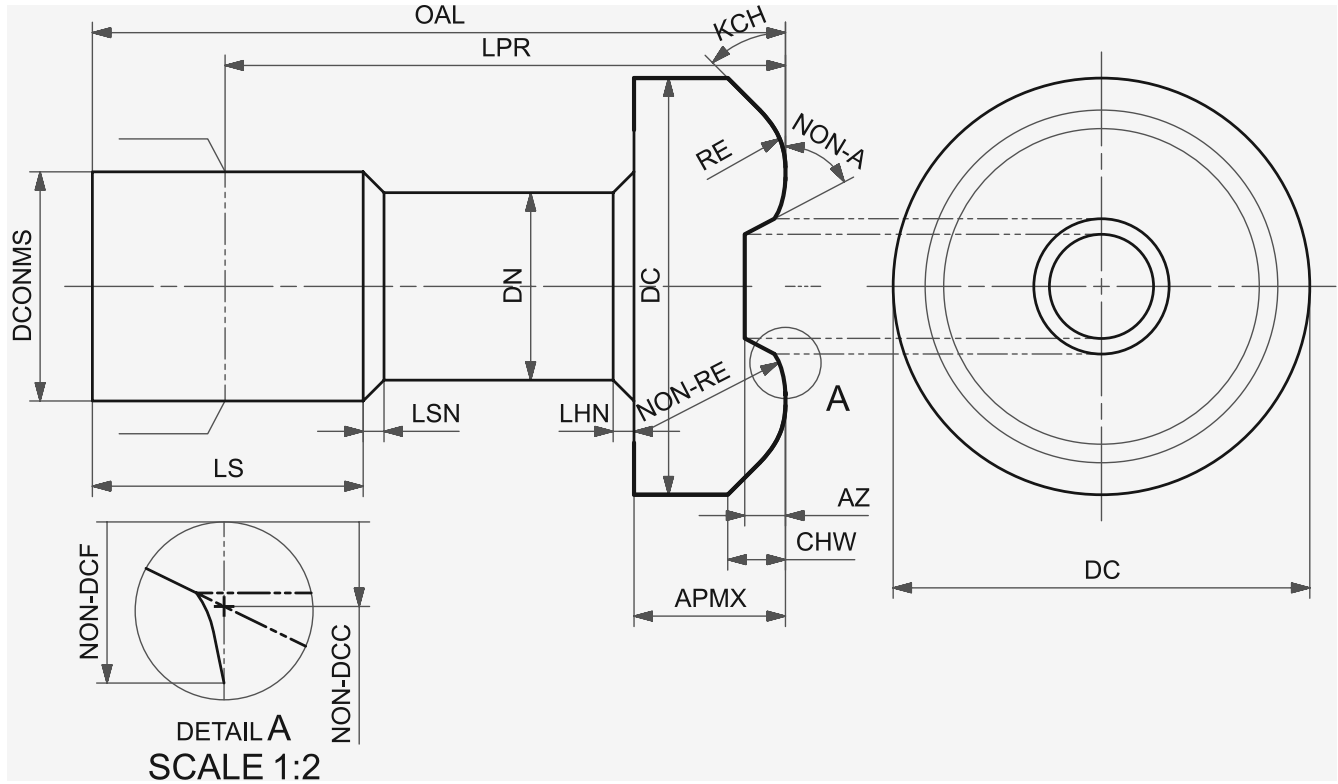


Figure 5.5: Depiction of a T-Slot End Mill

Additional remarks:

1. If none of U-RE, U-KCH, U-CHW, U-AZ, U-NON-DCF, U-NON-DCC, U-NON-A, U-NON-RE are given, RE, KCH, CHW, AZ, NON-DCF, NON-DCC, NON-A, NON-RE apply to the top and bottom sides of the cutting part.
2. If at least one of U-RE, U-KCH, U-CHW, U-AZ, U-NON-DCF, U-NON-DCC, U-NON-A, U-NON-RE is given, the top side of the of the cutting part is created from these parameters.

Symbol	Parameter Name	Type	Requirements
DC	CuttingDiameter	Length	Required
APMX	DepthOfCutMaximum	Length	Required
OAL	OverallLength	Length	Required
LPR	ProtrudingLength	Length	Optional
LS	ShankLength	Length	Optional
LSN	ShankChamferLength	Length	Optional
LHN	HeadChamferLength	Length	Optional
DN	NeckDiameter	Length	Optional
DCONMS	ShankDiameter	Length	Optional
RE	CornerRadius	Length	Optional
KCH	CornerChamferAngle	Angle	Optional
CHW	CornerChamferWidth	Length	Optional
AZ	PlungeDepthMaximum	Length	Optional
NON-DCF	NonCuttingDiameterFlat	Length	Optional
NON-DCC	NonCuttingDiameterCorner	Length	Optional
NON-A	NonCuttingAngle	Angle	Optional
NON-RE	NonCuttingCornerRadius	Length	Optional
U-RE	UpperCornerRadius	Length	Optional

Symbol	Parameter Name	Type	Requirements
U-KCH	UpperCornerChamferAngle	Angle	Optional
U-CHW	UpperCornerChamferWidth	Length	Optional
U-AZ	UpperPlungeDepthMaximum	Length	Optional
U-NON-DCF	UpperNonCuttingDiameterFlat	Length	Optional
U-NON-DCC	UpperNonCuttingDiameterCorner	Length	Optional
U-NON-A	UpperNonCuttingAngle	Angle	Optional
U-NON-RE	UpperNonCuttingCornerRadius	Length	Optional

5.1.6 Ball-Nosed End Mill

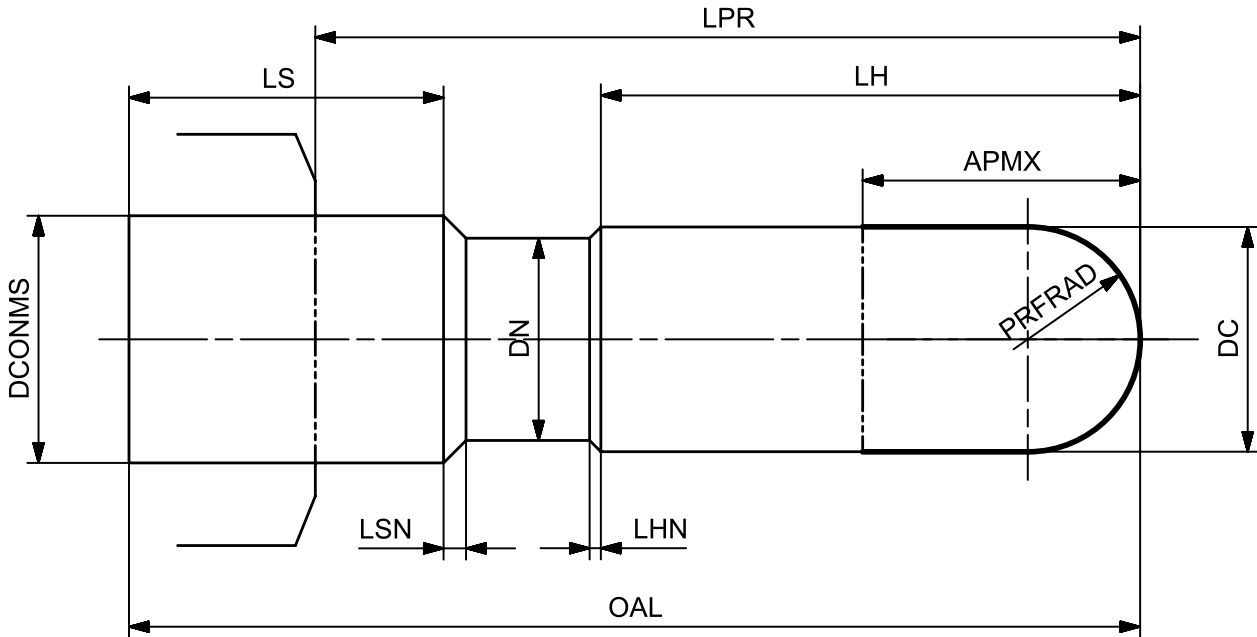


Figure 5.6: Depiction of a Ball-Nosed End Mill

Additional remarks:

1. If PRFRAD is not given, $DC/2$ is used.
2. If $PRFRAD < DC/2$ is given, $DC/2$ is used.
3. LH has to be at least as large as the tool tip profile arc height. If it is not given, and APMX is smaller than the tool tip profile arc height, it is clamped to the tool tip profile arc height.

Symbol	Parameter Name	Type	Requirements
DC	CuttingDiameter	Length	Required
APMX	DepthOfCutMaximum	Length	Required
OAL	OverallLength	Length	Required
LPR	ProtrudingLength	Length	Optional
LS	ShankLength	Length	Optional
LH	HeadLength	Length	Optional
LHN	HeadChamferLength	Length	Optional
LSN	ShankChamferLength	Length	Optional
DN	NeckDiameter	Length	Optional
DCONMS	ShankDiameter	Length	Optional
PRFRAD	ProfileRadius	Length	Optional

5.1.7 Die End Mill

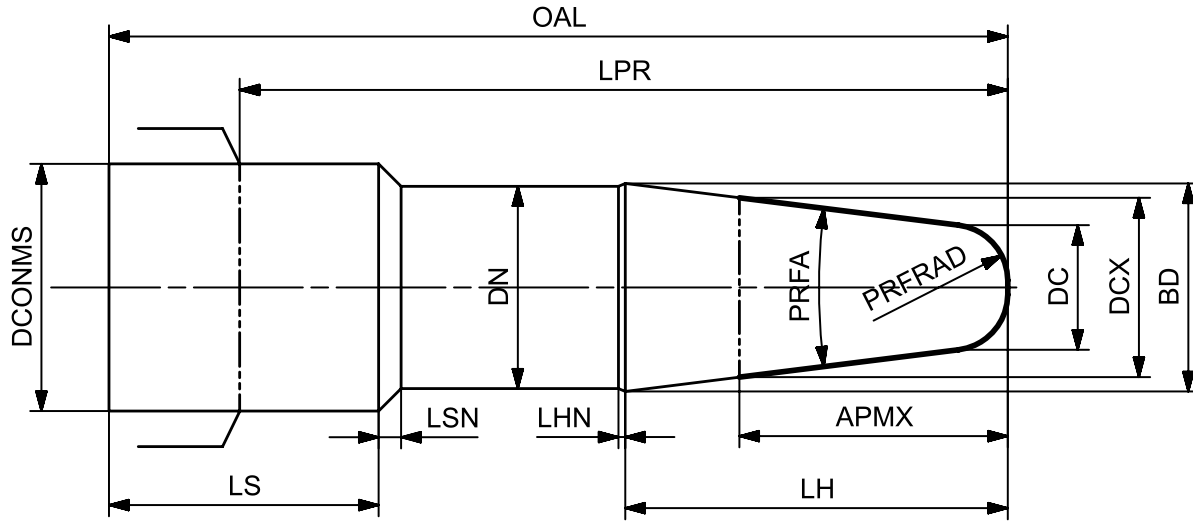


Figure 5.7: Depiction of a Die End Mill

Additional remarks:

1. If PRFRAD is not given, it is calculated to yield a continuous differentiable contour.
2. If DC and PRFRAD are both given, there are three cases for construction, depending on the relation between those two parameters:
 - In case PRFRAD is too small to fit the continuous differentiable shape at DC, construction resorts to the calculated PRFRAD from rule 1 (effectively ignoring the given PRFRAD).
 - In case PRFRAD is fitting the continuous differentiable shape at DC, both values are used and a continuous differentiable contour is constructed.
 - In case PRFRAD is too big to fit the continuous differentiable shape at DC, construction will yield a non continuous differentiable contour.
3. If more than one of DCX, BD and PRFA are available, DCX has highest priority, PRFA has second priority.

Symbol	Parameter Name	Type	Requirements
APMX	DepthOfCutMaximum	Length	Required
OAL	OverallLength	Length	Required
DC	CuttingDiameter	Length	1 of 2 Non-Optional with PRFRAD
PRFRAD	ProfileRadius	Length	1 of 2 Non-Optional with DC
DCX	CuttingDiameterMaximum	Length	1 of 3 Non-Optional with PRFA or BD
BD	BodyDiameter	Length	1 of 3 Non-Optional with PRFA or DCX
PRFA	ProfileAngle	Angle	1 of 3 Non-Optional with DCX or BD
LPR	ProtrudingLength	Length	Optional
LS	ShankLength	Length	Optional
LH	HeadLength	Length	Optional
DN	NeckDiameter	Length	Optional
LHN	HeadChamferLength	Length	Optional
LSN	ShankChamferLength	Length	Optional

Symbol	Parameter Name	Type	Requirements
DCONMS	ShankDiameter	Length	Optional

5.1.8 Concave Rounded Profile End Mill

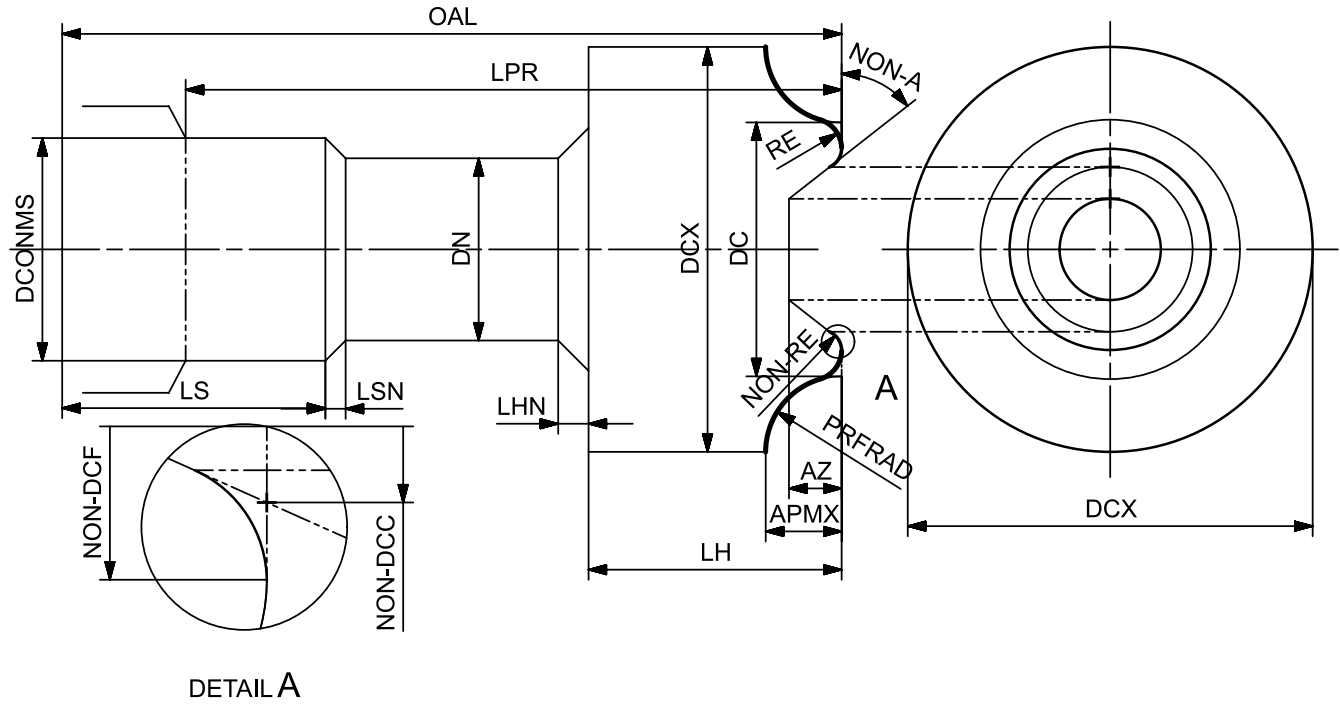


Figure 5.8: Depiction of a Concave Rounded Profile End Mill

Symbol	Parameter Name	Type	Requirements
DC	CuttingDiameter	Length	Required
DCX	CuttingDiameterMaximum	Length	Required
APMX	DepthOfCutMaximum	Length	Required
OAL	OverallLength	Length	Required
PRFRAD	ProfileRadius	Length	Required
LPR	ProtrudingLength	Length	Optional
LS	ShankLength	Length	Optional
LH	HeadLength	Length	Optional
LHN	HeadChamferLength	Length	Optional
LSN	ShankChamferLength	Length	Optional
DN	NeckDiameter	Length	Optional
DCONMS	ShankDiameter	Length	Optional
RE	CornerRadius	Length	Optional
AZ	PlungeDepthMaximum	Length	Optional
NON-DCF	NonCuttingDiameter Flat	Length	Optional
NON-DCC	NonCuttingDiameter Corner	Length	Optional
NON-A	NonCuttingAngle	Angle	Optional
NON-RE	NonCuttingCornerRadius	Length	Optional

5.1.9 Thread End Mill

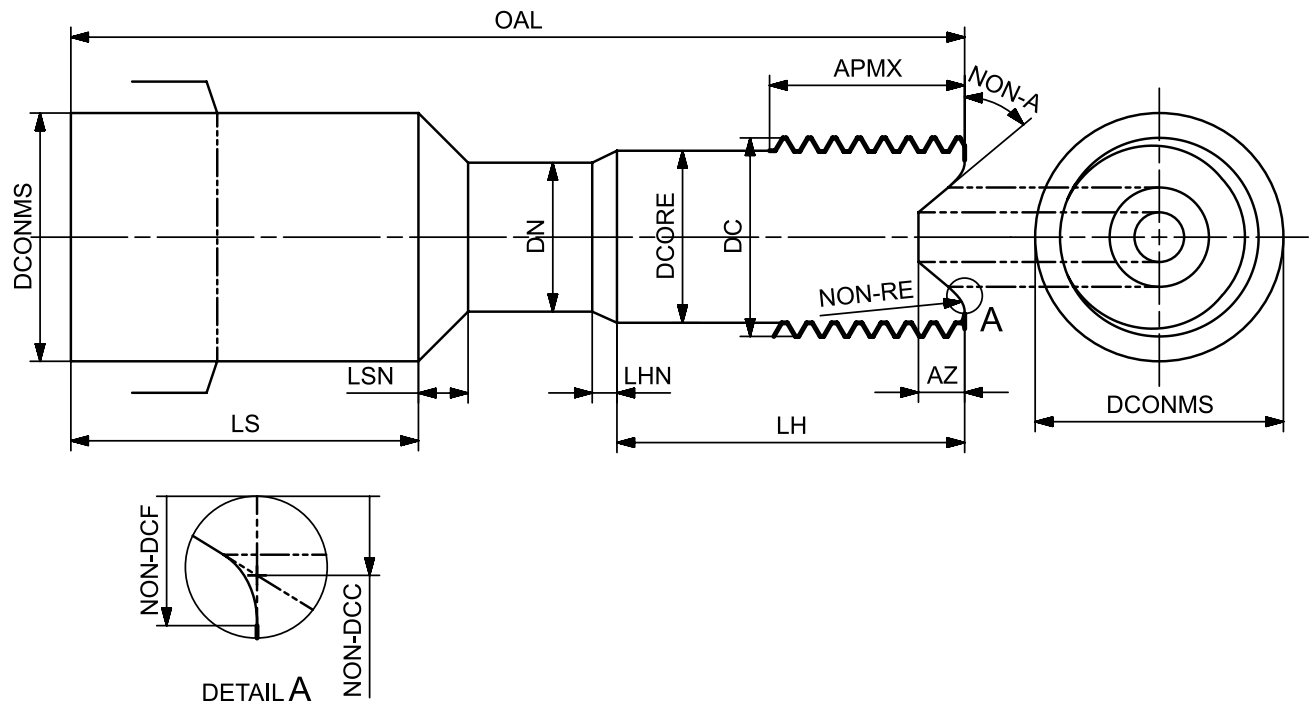


Figure 5.9: Depiction of a Thread End Mill

Symbol	Parameter Name	Type	Requirements
DC	CuttingDiameter	Length	Required
DCORE	CoreDiameter	Length	Required
APMX	DepthOfCutMaximum	Length	Required
OAL	OverallLength	Length	Required
TP	ThreadPitch	Length	1 of 2 Non-Optional with TPI
TPI	ThreadsPerInch	Float	1 of 2 Non-Optional with TP
LPR	ProtrudingLength	Length	Optional
LS	ShankLength	Length	Optional
LH	HeadLength	Length	Optional
LHN	HeadChamferLength	Length	Optional
LSN	ShankChamferLength	Length	Optional
DCONMS	ShankDiameter	Length	Optional
DN	NeckDiameter	Length	Optional
AZ	PlungeDepthMaximum	Length	Optional
NON-DCF	NonCuttingDiameter Flat	Length	Optional
NON-DCC	NonCuttingDiameter Corner	Length	Optional
NON-A	NonCuttingAngle	Angle	Optional
NON-RE	NonCuttingCornerRadius	Length	Optional

5.1.10 Cutting Stylus

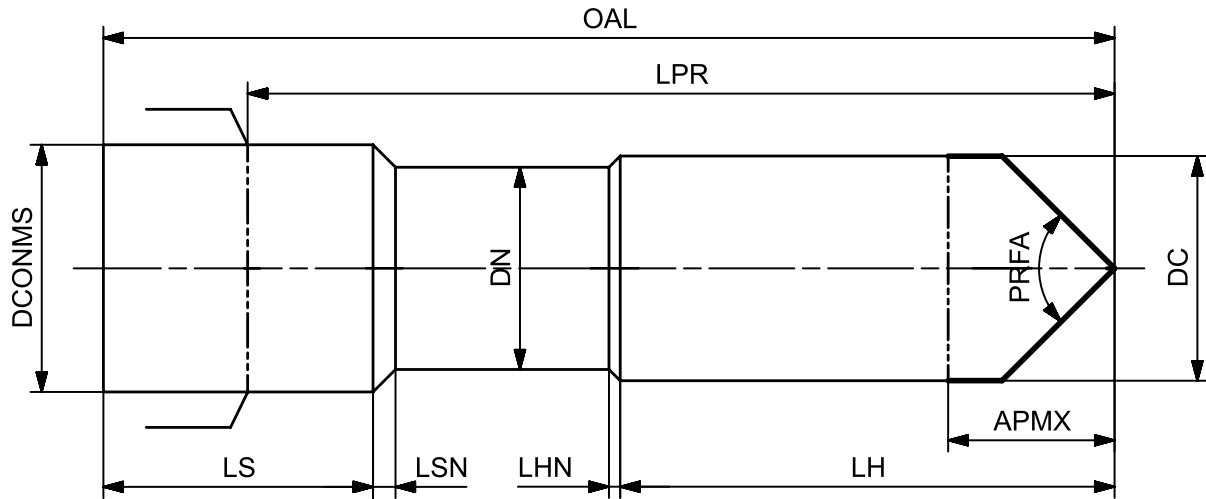


Figure 5.10: Depiction of a Cutting Stylus

Symbol	Parameter Name	Type	Requirements
DC	CuttingDiameter	Length	Required
APMX	DepthOfCutMaximum	Length	Required
OAL	OverallLength	Length	Required
PRFA	ProfileAngle	Angle	Required
LPR	ProtrudingLength	Length	Optional
LS	ShankLength	Length	Optional
LH	HeadLength	Length	Optional
LHN	HeadChamferLength	Length	Optional
LSN	ShankChamferLength	Length	Optional
DN	NeckDiameter	Length	Optional
DCONMS	ShankDiameter	Length	Optional

5.1.11 Thread End Mill With Drilling Part

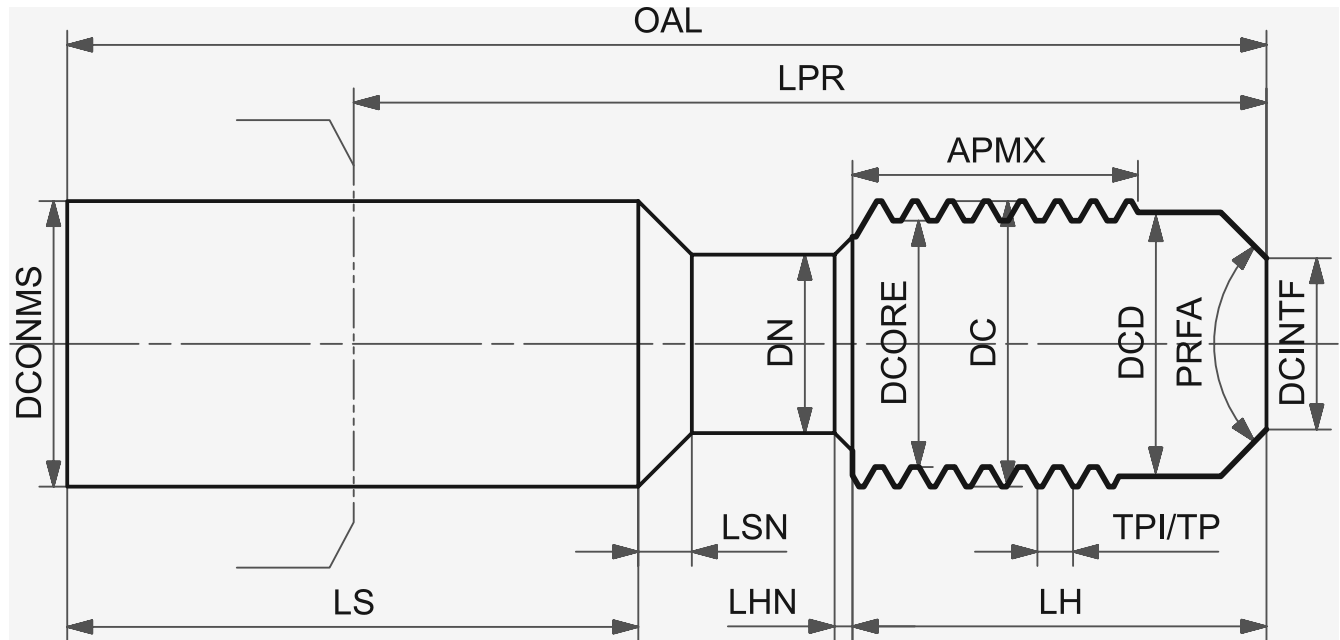


Figure 5.11: Depiction of a Thread End Mill With Drilling Part

Additional remarks:

- 1) If DN is not given, it is taken as DCORE.
- 2) If DCINTF is not given, it is taken as 0.
- 3) DCD must be less than or equal to DC.

Symbol	Parameter Name	Type	Requirements
DC	CuttingDiameter	Length	Required
DCD	CuttingDiameterDrillingPart	Length	Required
APMX	DepthOfCutMaximum	Length	Required
OAL	OverallLength	Length	Required
PRFA	ProfileAngle	Angle	Required
DCORE	CoreDiameter	Length	Required
DCINTF	InterferenceCuttingDiameter	Length	Optional
TP	ThreadPitch	Length	1 of 2 Non-Optional with TPI
TPI	ThreadsPerInch	Float	1 of 2 Non-Optional with TP
LPR	ProtrudingLength	Length	Optional
LS	ShankLength	Length	Optional
LH	HeadLength	Length	Optional
LHN	HeadChamferLength	Length	Optional
LSN	ShankChamferLength	Length	Optional
DCONMS	ShankDiameter	Length	Optional
DN	NeckDiameter	Length	Optional

5.2 Other Solid Endmills

With respect to the symbols for specific parameters used in the following a few rules regarding evaluation of the parameters as well as default values are used:

1. LHN and LSN are zero by default.
2. If LH is not given, APMX is used as value.
3. If LS is not given, it is computed as $OAL - LH - LHN - LSN$.

5.2.1 Thread Mill Single Form

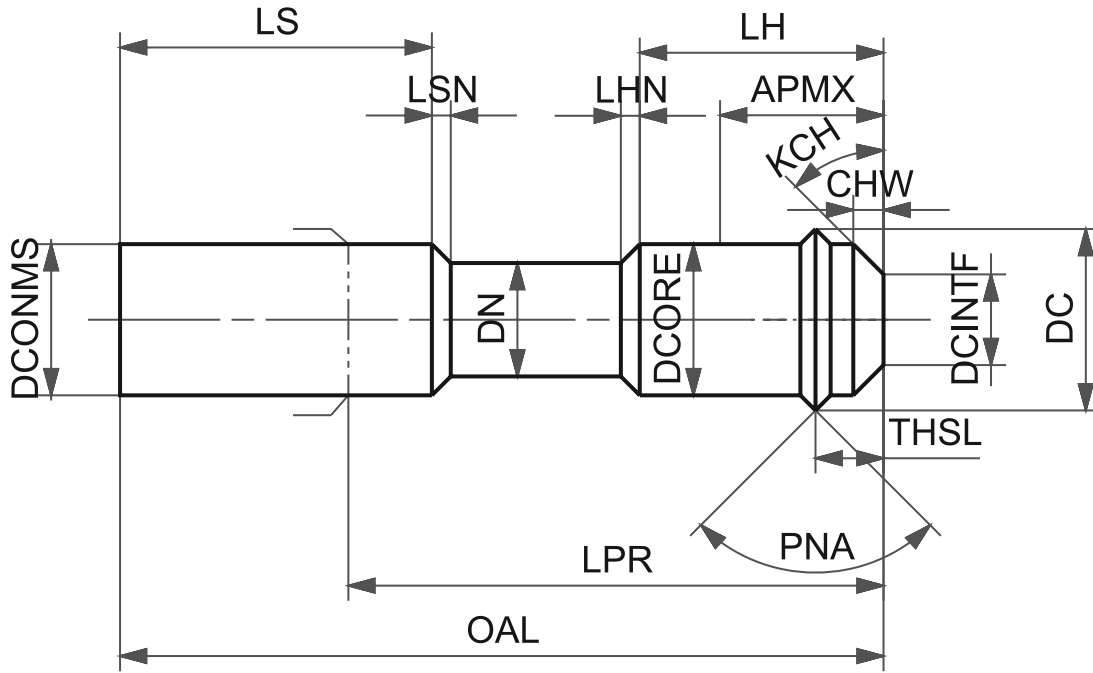


Figure 5.12: Depiction of a Thread Mill Single Form

Additional remarks:

1. If DCONMS is not given, DCORE is used.
2. Of the parameters KCH, CHW and DCINTF, either none or exactly two have to be given (if all are given they should match).
3. If THSL is not given, the minimum possible value is used.

Symbol	Parameter Name	Type	Requirements
DC	CuttingDiameter	Length	Required
DCORE	CoreDiameter	Length	Required
APMX	DepthOfCutMaximum	Length	Required
PNA	ProfileIncludedAngle	Angle	Required
OAL	OverallLength	Length	Required
LPR	ProtrudingLength	Length	Optional
LS	ShankLength	Length	Optional
LH	HeadLength	Length	Optional
LHN	HeadChamferLength	Length	Optional
LSN	ShankChamferLength	Length	Optional
DCONMS	ShankDiameter	Length	Optional
DN	NeckDiameter	Length	Optional
KCH	CornerChamferAngle	Angle	Optional (see remark)
CHW	CornerChamferWidth	Length	Optional (see remark)

Symbol	Parameter Name	Type	Requirements
DCINTF	InterferenceCuttingDiameter	Length	Optional (see remark)
THSL	ThreadStartLength	Length	Optional

5.2.2 Drilling Thread Whirler

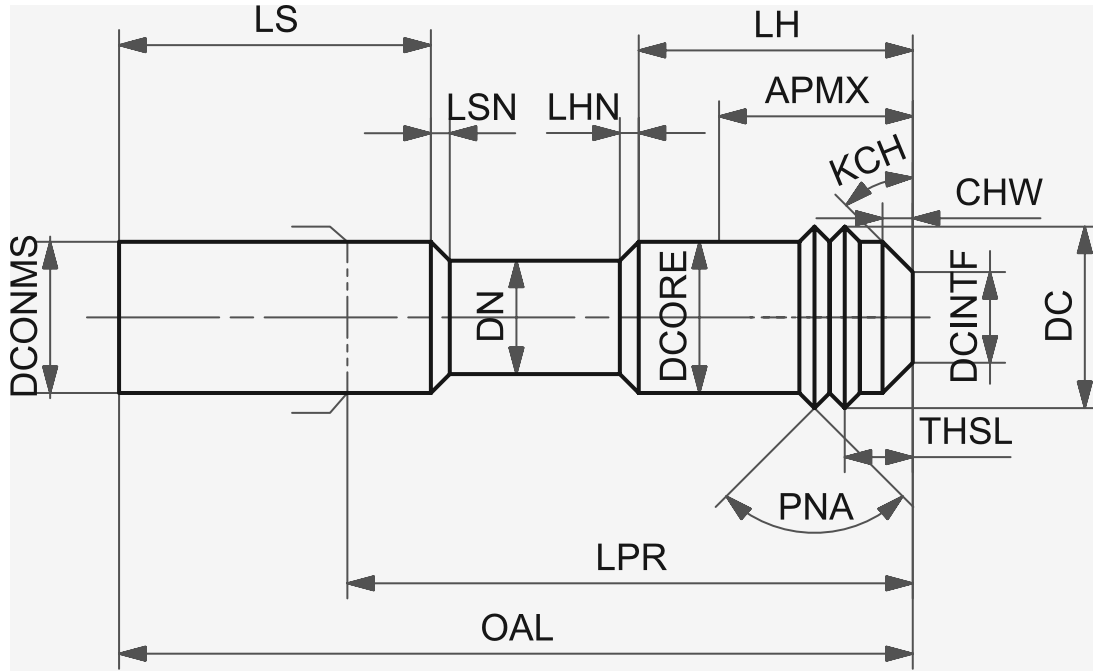


Figure 5.13: Depiction of a Drilling Thread Whirler

Additional remarks:

1. If DCONMS is not given, DCORE is used.
2. Of the parameters KCH, CHW and DCINTF, either none or exactly two have to be given (if all are given they should match).
3. If THSL is not given, the minimum possible value is used.

Symbol	Parameter Name	Type	Requirements
DC	CuttingDiameter	Length	Required
DCORE	CoreDiameter	Length	Required
APMX	DepthOfCutMaximum	Length	Required
PNA	ProfileIncludedAngle	Angle	Required
OAL	OverallLength	Length	Required
THN	NumberOfThread	Integer	Required
THSL	ThreadStartLength	Length	Optional
LPR	ProtrudingLength	Length	Optional
LS	ShankLength	Length	Optional
LH	HeadLength	Length	Optional
LHN	HeadChamferLength	Length	Optional
LSN	ShankChamferLength	Length	Optional
DCONMS	ShankDiameter	Length	Optional
DN	NeckDiameter	Length	Optional
KCH	CornerChamferAngle	Angle	Optional (see remark)
CHW	CornerChamferWidth	Length	Optional (see remark)
DCINTF	InterferenceCuttingDiameter	Length	Optional (see remark)

5.2.3 Lollipop Mill

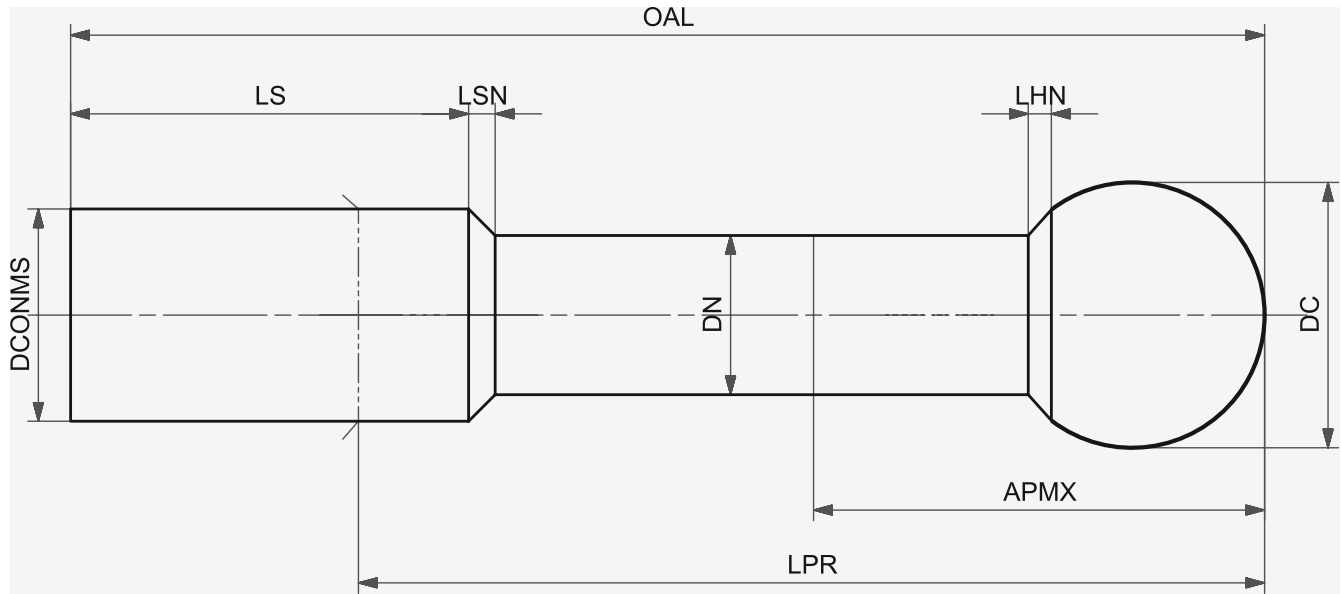


Figure 5.14: Depiction of a Lollipop Mill

Additional remarks:

1. DN is required if APMX is 0.

Symbol	Parameter Name	Type	Requirements
APMX	DepthOfCutMaximum	Length	Required
OAL	OverallLength	Length	Required
DC	CuttingDiameter	Length	1 of 2 Non-Optional with DN
DN	NeckDiameter	Length	1 of 2 Non-Optional with DC
LPR	ProtrudingLength	Length	Optional
LS	ShankLength	Length	Optional
LSN	ShankChamferLength	Length	Optional
LHN	HeadChamferLength	Length	Optional
DCONMS	ShankDiameter	Length	Optional

5.2.4 Barrel Mill

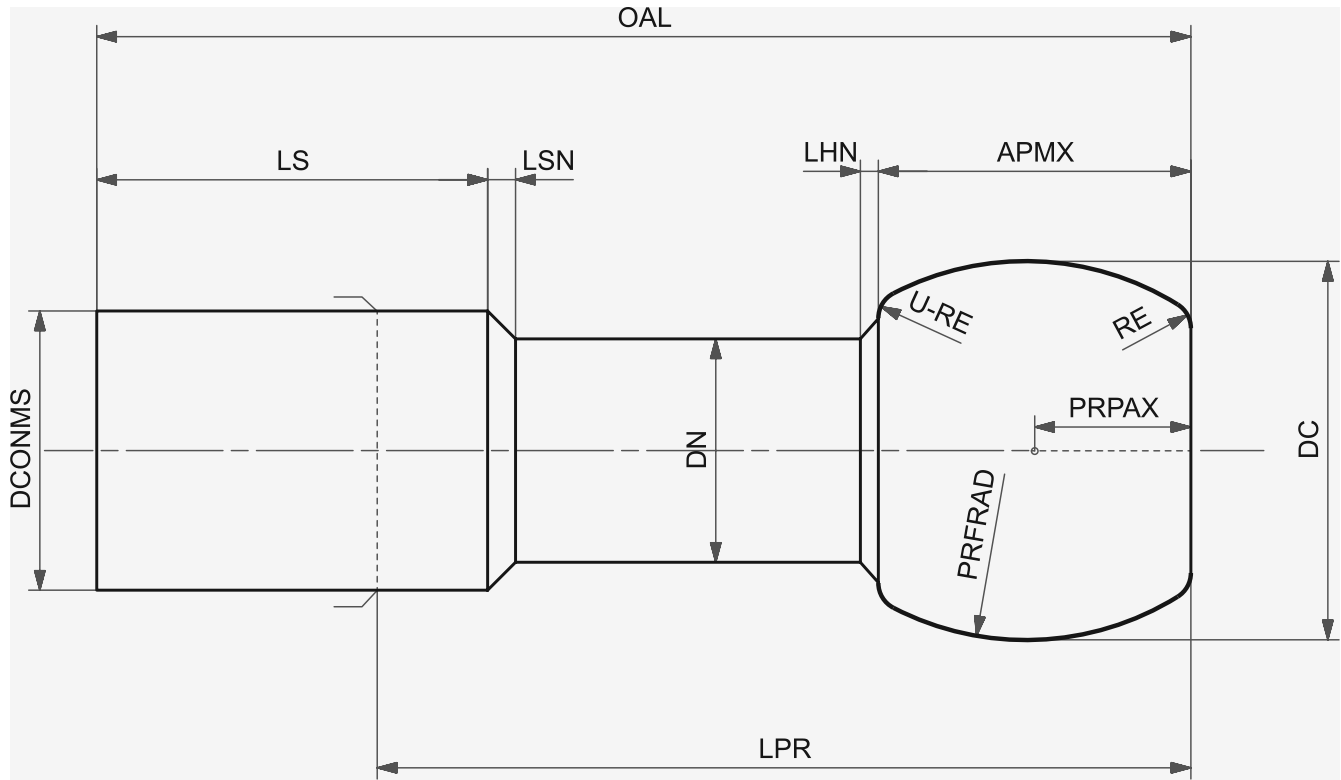


Figure 5.15: Depiction of a Barrel Mill

Additional remarks:

- 1) If $PRPAX$ is not given, it equals $APMX / 2$.

Symbol	Parameter Name	Type	Requirements
DC	CuttingDiameter	Length	Required
APMX	DepthOfCutMaximum	Length	Required
OAL	OverallLength	Length	Required
PRFRAD	ProfileRadius	Length	Required
PRPAX	ProfilePositionAxial	Length	Optional
LPR	ProtrudingLength	Length	Optional
LS	ShankLength	Length	Optional
LSN	ShankChamferLength	Length	Optional
LHN	HeadChamferLength	Length	Optional
DN	NeckDiameter	Length	Optional
DCONMS	ShankDiameter	Length	Optional
RE	CornerRadius	Length	Optional
U-RE	UpperCornerRadius	Length	Optional

5.3 Solid reamers (Compatible with ISO 13399-311)

With respect to the symbols for specific parameters used in the following a few rules regarding evaluation of the parameters as well as default values are used:

1. LHN and LSN are zero by default.
2. If LS is not given, it is computed as $OAL - APMX - LHN - LSN$.

5.3.1 Cylindrical Reamer

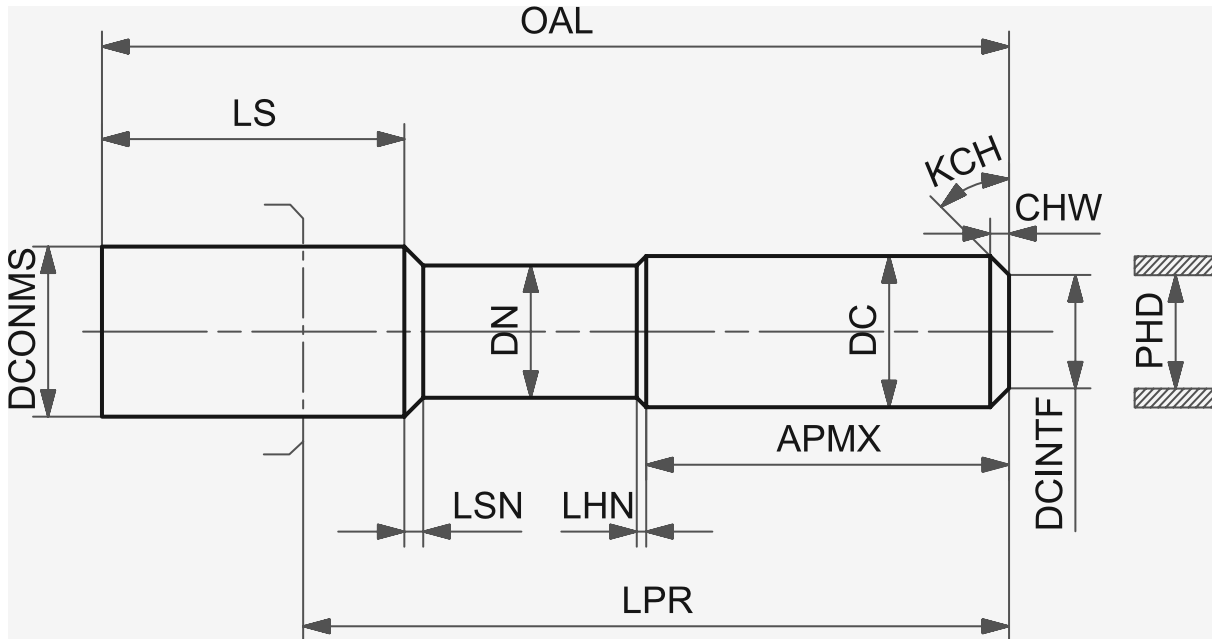


Figure 5.16: Depiction of a Cylindrical Reamer

Additional remarks:

1. Of the parameters KCH, CHW and DCINTF, either none or exactly two have to be given (if all are given they should match).

Symbol	Parameter Name	Type	Requirements
DC	CuttingDiameter	Length	Required
APMX	DepthOfCutMaximum	Length	Required
OAL	OverallLength	Length	Required
KCH	CornerChamferAngle	Angle	Optional (see remark)
CHW	CornerChamferWidth	Length	Optional (see remark)
DCINTF	InterferenceCuttingDiameter	Length	Optional (see remark)
LPR	ProtrudingLength	Length	Optional
LS	ShankLength	Length	Optional
LSN	ShankChamferLength	Length	Optional
LHN	HeadChamferLength	Length	Optional
DN	NeckDiameter	Length	Optional
DCONMS	ShankDiameter	Length	Optional
PHD	PremachinedHoleDiameter	Length	Optional

5.4 Solid Thread Cutting Tap (Compatible with ISO 13399-301.2)

With respect to the symbols for specific parameters used in the following a few rules regarding evaluation of the parameters as well as default values are used:

1. LSN is zero by default.
2. If LS is not given, it is computed as $OAL - APMX - LSN$.

5.4.1 Thread Cutting Tap With Shank

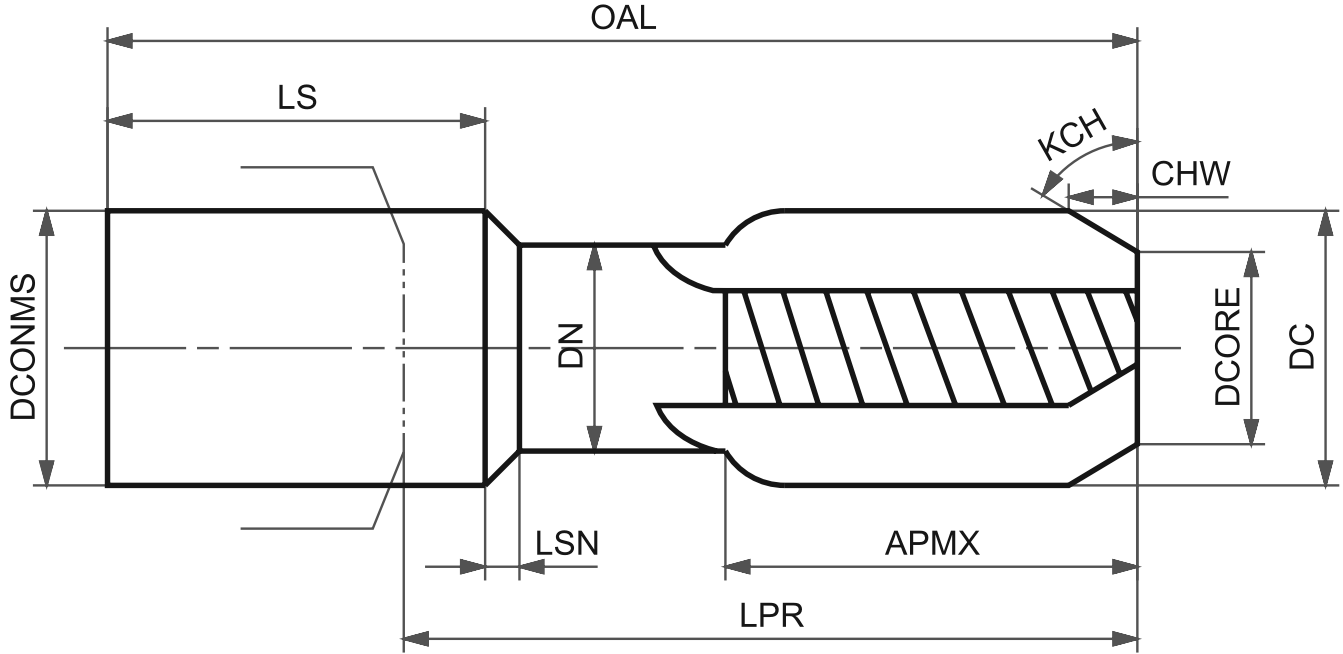


Figure 5.17: Depiction of a Thread Cutting Tap With Shank

Additional remarks:

- 1) If KCH and CHW are given CHW is used (KCH should match).

Symbol	Parameter Name	Type	Requirements
DC	CuttingDiameter	Length	Required
DCORE	CoreDiameter	Length	Required
APMX	DepthOfCutMaximum	Length	Required
OAL	OverallLength	Length	Required
TP	ThreadPitch	Length	1 of 2 Non-Optional with TPI
TPI	ThreadsPerInch	Float	1 of 2 Non-Optional with TP
LPR	ProtrudingLength	Length	Optional
LS	ShankLength	Length	Optional
LSN	ShankChamferLength	Length	Optional
DN	NeckDiameter	Length	Optional
DCONMS	ShankDiameter	Length	Optional
CHW	CornerChamferWidth	Length	Optional (see remark)
KCH	CornerChamferAngle	Angle	Optional (see remark)

5.5 Solid Drills (Compatible with ISO 13399-302)

In the following subchapters parametric tool models for solid drills are defined.

With respect to the symbols for specific parameters used in the following a few rules regarding evaluation of the parameters as well as default values are used (if not stated otherwise for a specific tool):

1. If DCONMS is not given, DC is taken.
2. If LS is not given, the value is calculated as $OAL - LU - LHN - LSN$.
3. If multiple parameters are given in order to define the tip of the drill the order is taken as follows: PL has highest priority, SIG has second priority, calculation from LF and OAL is used last.
4. LHN and LSN are 0 by default.
5. If DN is not given, DC is used.

5.5.1 Twist Drill

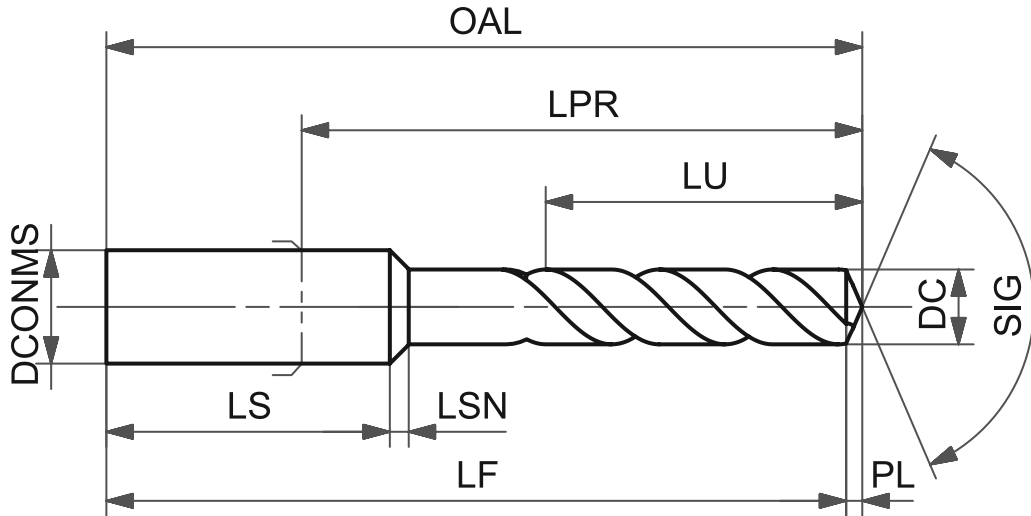


Figure 5.18: Depiction of a Twist Drill

Symbol	Parameter Name	Type	Requirements
DC	CuttingDiameter	Length	Required
LU	UsableLength	Length	Required
OAL	OverallLength	Length	Required
PL	PointLength	Length	1 of 3 Non-Optional with SIG or LF
SIG	PointAngle	Angle	1 of 3 Non-Optional with PL or LF
LF	FunctionalLength	Length	1 of 3 Non-Optional with SIG or PL
LPR	ProtrudingLength	Length	Optional
LS	ShankLength	Length	Optional
LSN	ShankChamferLength	Length	Optional
DCONMS	ShankDiameter	Length	Optional

5.5.2 Spot Drill

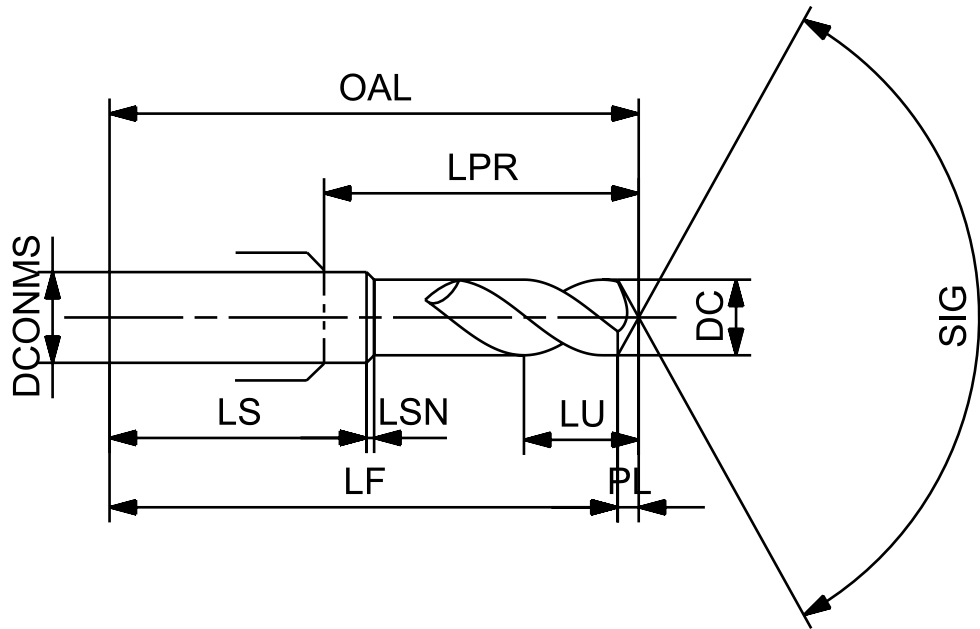


Figure 5.19: Depiction of a Spot Drill

Symbol	Parameter Name	Type	Requirements
DC	CuttingDiameter	Length	Required
LU	UsableLength	Length	Required
OAL	OverallLength	Length	Required
PL	PointLength	Length	1 of 3 Non-Optional with SIG or LF
SIG	PointAngle	Angle	1 of 3 Non-Optional with PL or LF
LF	FunctionalLength	Length	1 of 3 Non-Optional with SIG or PL
LPR	ProtrudingLength	Length	Optional
LS	ShankLength	Length	Optional
LSN	ShankChamferLength	Length	Optional
DCONMS	ShankDiameter	Length	Optional

5.5.3 Counterbore Drill

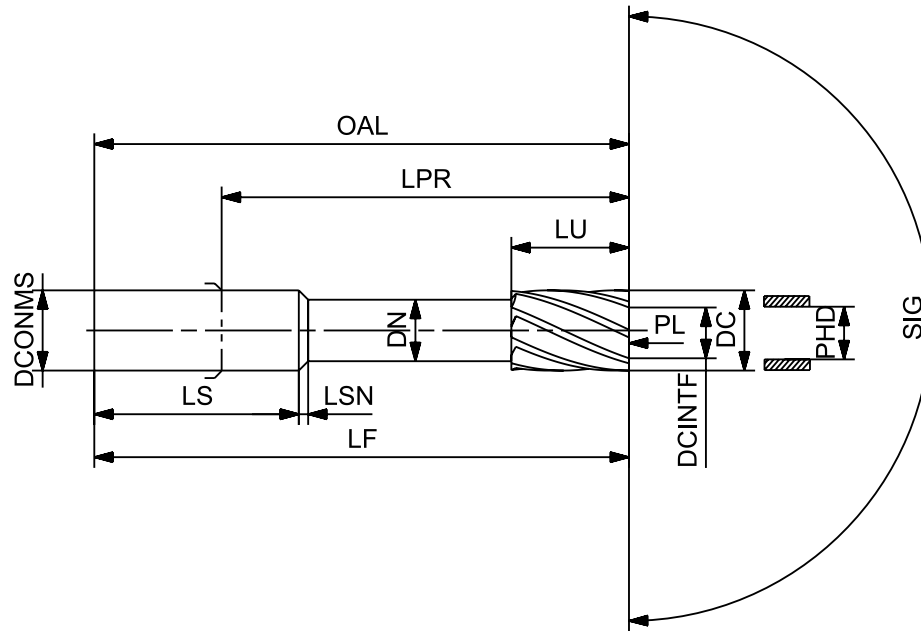


Figure 5.20: Depiction of a Counterbore Drill

Additional remarks:

- 1) If DCINTF is not given, 50% of DC is used.

Symbol	Parameter Name	Type	Requirements
DC	CuttingDiameter	Length	Required
LU	UsableLength	Length	Required
OAL	OverallLength	Length	Required
PL	PointLength	Length	1 of 3 Non-Optional with SIG or LF
SIG	PointAngle	Angle	1 of 3 Non-Optional with PL or LF
LF	FunctionalLength	Length	1 of 3 Non-Optional with SIG or PL
LPR	ProtrudingLength	Length	Optional
LS	ShankLength	Length	Optional
LSN	ShankChamferLength	Length	Optional
DCINTF	InterferenceCuttingDiameter	Length	Optional
PHD	PremachinedHoleDiameter	Length	Optional
DN	NeckDiameter	Length	Optional
DCONMS	ShankDiameter	Length	Optional

5.5.4 Center Drill

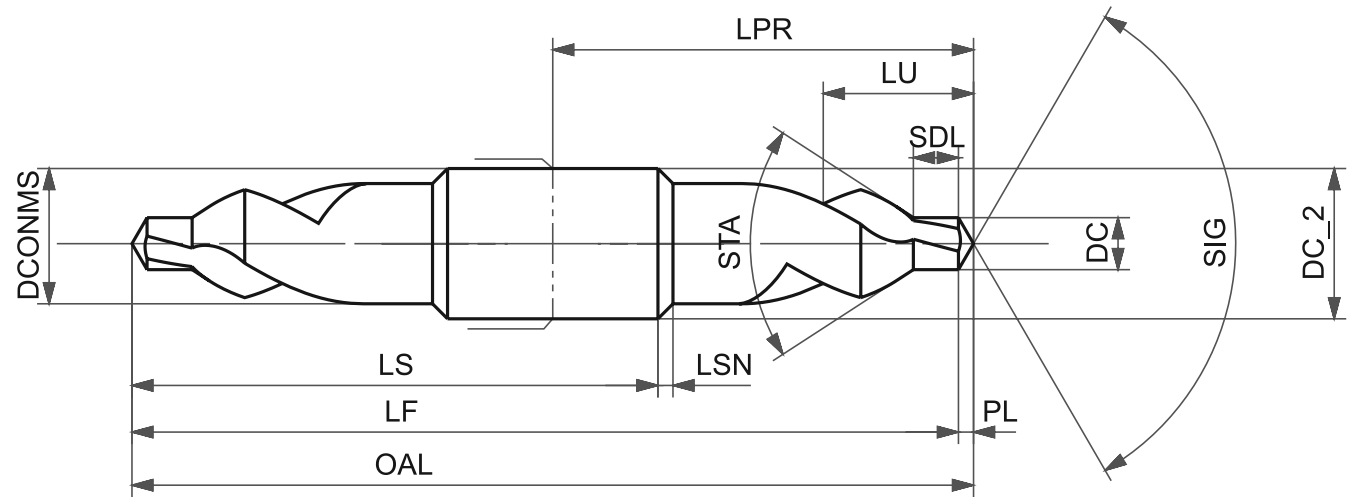


Figure 5.21: Depiction of a Center Drill

Additional remarks:

- 1) If DCONMS is not given, DC_2 is used.

Symbol	Parameter Name	Type	Requirements
DC	CuttingDiameter	Length	Required
DC_2	CuttingDiameter2	Length	Required
LU	UsableLength	Length	Required
OAL	OverallLength	Length	Required
SDL	StepDiameterLength	Length	Required
STA	StepIncludedAngle	Angle	Required
PL	PointLength	Length	1 of 3 Non-Optional with SIG or LF
SIG	PointAngle	Angle	1 of 3 Non-Optional with PL or LF
LF	FunctionallLength	Length	1 of 3 Non-Optional with SIG or PL
LPR	ProtrudingLength	Length	Optional
LS	ShankLength	Length	Optional
LSN	ShankChamferLength	Length	Optional
DCONMS	ShankDiameter	Length	Optional

5.5.5 StepDrill

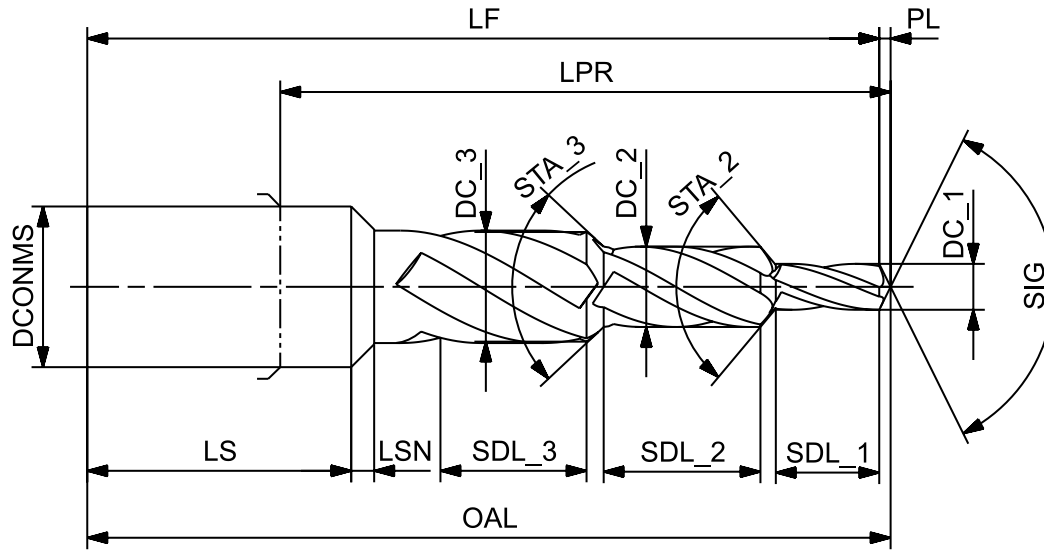


Figure 5.22: Depiction of a Step Drill

Additional remarks:

- 1) If STA_2 or STA_3 is not given, but the step is present it is taken as 180°.
- 2) If SDL_3 or DC_3 is not given, SDL_3 = 0 is used (i.e. the third step is omitted).
- 3) If LS is not given it is calculated from OAL and the total length of all steps including their chamfers.
- 4) If DCONMS is not given, DC_3 is used. If DC_3 is not available, DC_2 is used instead.

Symbol	Parameter Name	Type	Requirements
DC_1	CuttingDiameterFirstStep	Length	Required
DC_2	CuttingDiameterSecondStep	Length	Required
DC_3	CuttingDiameterThirdStep	Length	Optional
SDL_1	StepDiameterLengthFirstStep	Length	Required
SDL_2	StepDiameterLengthSecondStep	Length	Required
SDL_3	StepDiameterLengthThirdStep	Length	Optional
STA_2	StepIncludedAngleSecondStep	Angle	Optional
STA_3	StepIncludedAngleThirdStep	Angle	Optional
OAL	OverallLength	Length	Required
PL	PointLength	Length	1 of 3 Non-Optional with SIG or LF
SIG	PointAngle	Angle	1 of 3 Non-Optional with PL or LF
LF	FunctionalLength	Length	1 of 3 Non-Optional with SIG or PL
LS	ShankLength	Length	Optional
LSN	ShankChamferLength	Length	Optional
LPR	ProtrudingLength	Length	Optional
DCONMS	ShankDiameter	Length	Optional

5.5.6 Tapered Countersinking Drill

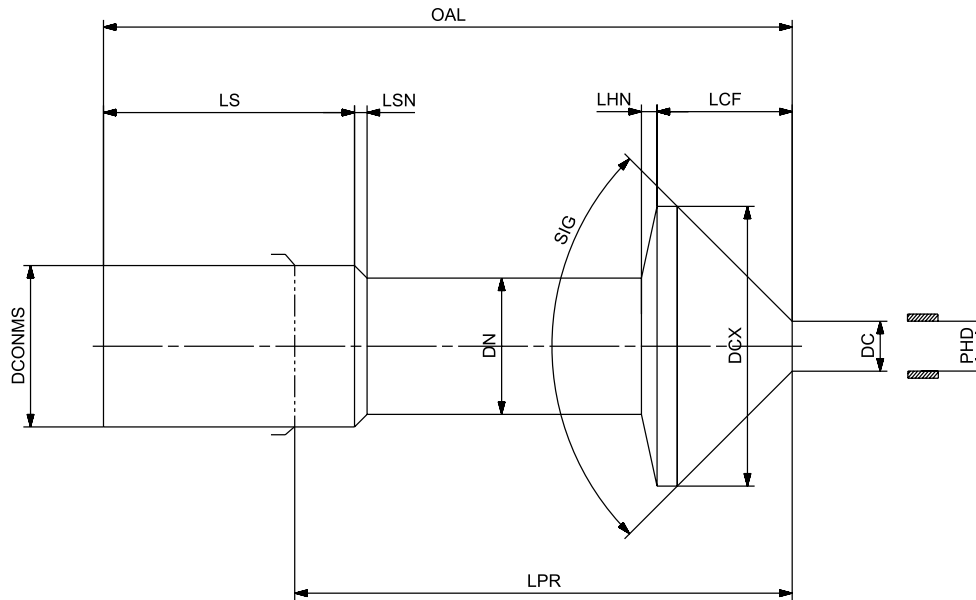


Figure 5.23: Depiction of a Tapered Countersinking Drill

Additional remarks:

- 1) If LS is not given, $OAL - LCF - LHN - LSN$ is used.
- 2) If DN or DCONMS is not given, DCX is used as a fallback.

Symbol	Parameter Name	Type	Requirements
DC	CuttingDiameter	Length	Required
DCX	CuttingDiameterMaximum	Length	Required
SIG	PointAngle	Angle	Required
LCF	ChipFluteLength	Length	Required
OAL	OverallLength	Length	Required
PHD	PremachinedHoleDiameter	Length	Optional
LHN	HeadChamferLength	Length	Optional
DN	NeckDiameter	Length	Optional
LS	ShankLength	Length	Optional
LSN	ShankChamferLength	Length	Optional
LPR	ProtrudingLength	Length	Optional
DCONMS	ShankDiameter	Length	Optional

5.5.7 Core Drill

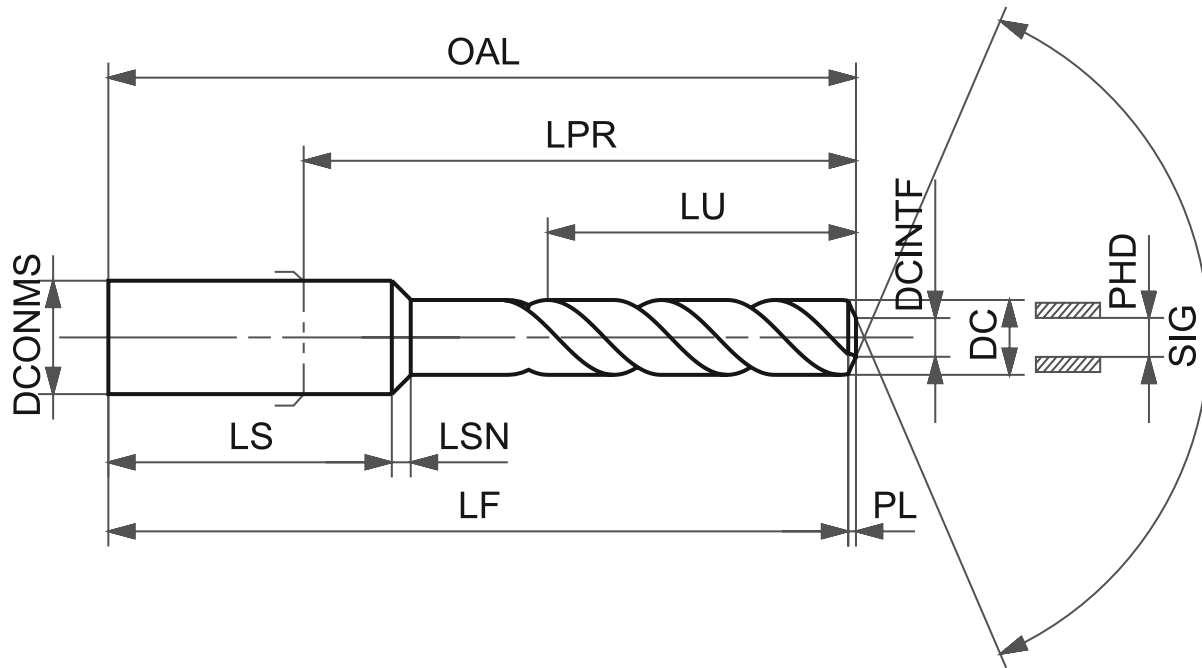


Figure 5.24: Depiction of a Core Drill

Additional remarks:

- 1) If DCINTF is not given, 0 is used.

Symbol	Parameter Name	Type	Requirements
DC	CuttingDiameter	Length	Required
LU	UsableLength	Length	Required
OAL	OverallLength	Length	Required
PL	PointLength	Length	1 of 3 Non-Optional with SIG or LF
SIG	PointAngle	Angle	1 of 3 Non-Optional with PL or LF
LF	FunctionalLength	Length	1 of 3 Non-Optional with SIG or PL
LPR	ProtrudingLength	Length	Optional
LS	ShankLength	Length	Optional
LSN	ShankChamferLength	Length	Optional
DCONMS	ShankDiameter	Length	Optional
DCINTF	InterferenceCuttingDiameter	Length	Optional
PHD	PremachinedHoleDiameter	Length	Optional

5.6 Solid Probes (Compatible with DIN4000)

5.6.1 Probe With Straight Shank

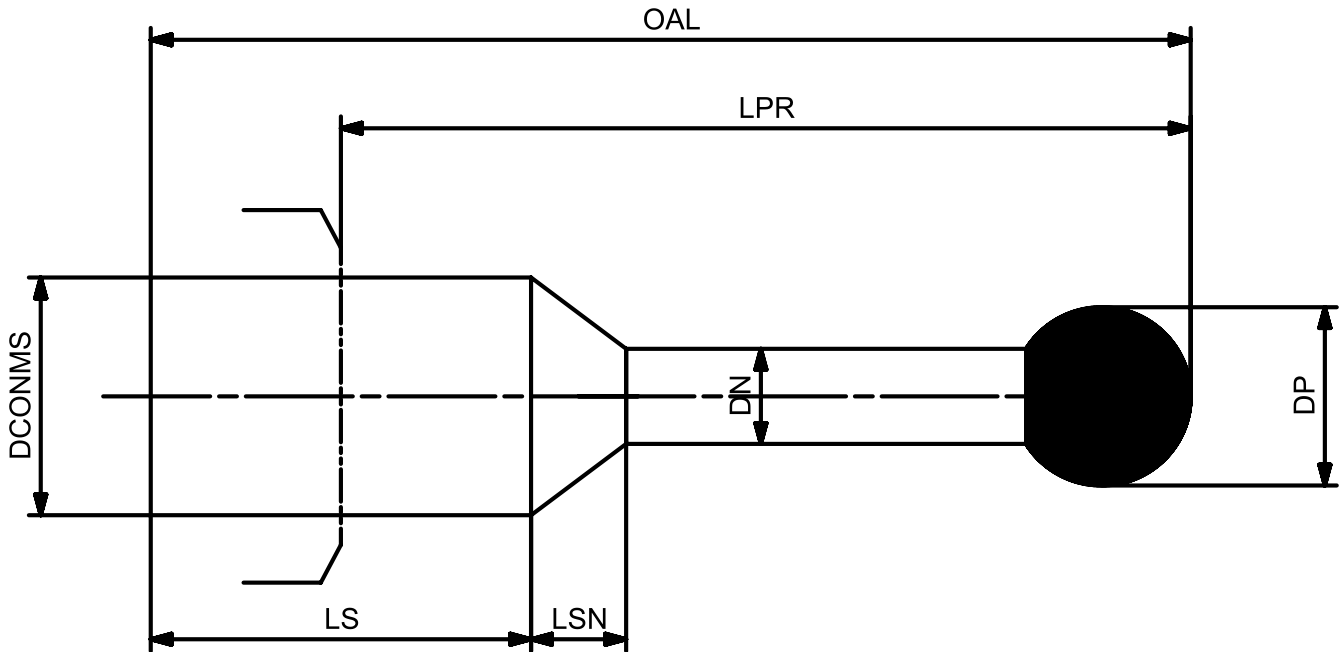


Figure 5.25: Depiction of a Probe With Straight Shank

Symbol	Parameter Name	Type	Requirements
DP	ProbingDiameter	Length	Required
DN	NeckDiameter	Length	Required
LS	ShankLength	Length	Required
OAL	OverallLength	Length	Required
LPR	ProtrudingLength	Length	Optional
LSN	ShankChamferLength	Length	Optional
DCONMS	ShankDiameter	Length	Optional

5.7 Cutting Inserts (Compatible with ISO13399 - 201)

In the following subchapters parametric models for cutting inserts are defined.

With respect to the symbols for specific parameters used in the following a few rules regarding evaluation of the parameters as well as default values are used:

1. If AN is not given, 0 is used.
2. If both L and IC are given, IC is used.

5.7.1 Parallelogram Insert

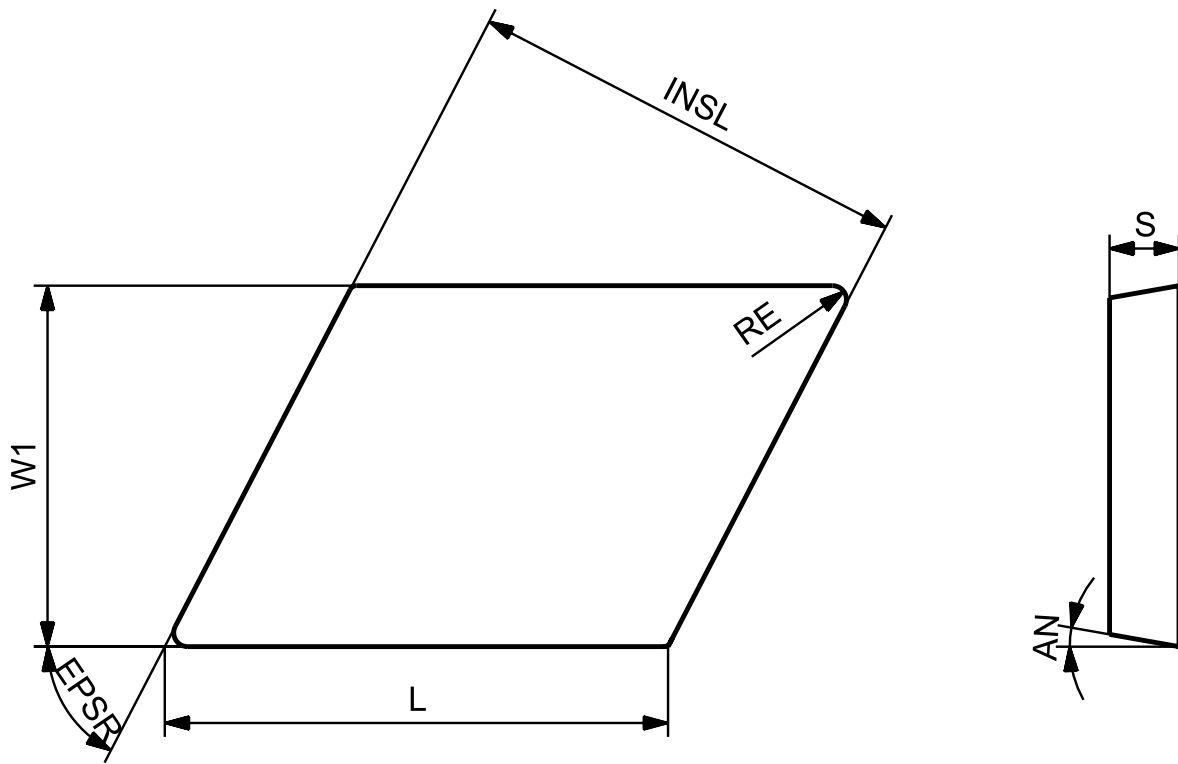


Figure 5.26: Depiction of a Parallelogram Insert

Additional remarks:

- 1) If both L and $INS L$ are given, $INS L$ is used.
- 2) $SMIR$ defaults to False if not given from previous versions.

Symbol	Parameter Name	Type	Requirements
$W1$	InsertWidth	Length	Required
RE	CornerRadius	Length	Required
$EPSR$	InsertIncludedAngle	Angle	Required
S	InsertThickness	Length	Required
$SMIR$	MirrorBaseShape	Bool	Required
$INS L$	InsertLength	Length	1 of 2 Non-Optional with L
L	CuttingEdgeLength	Length	1 of 2 Non-Optional with $INS L$
AN	ClearanceAngleMajor	Angle	Optional

5.7.2 Triangular Insert

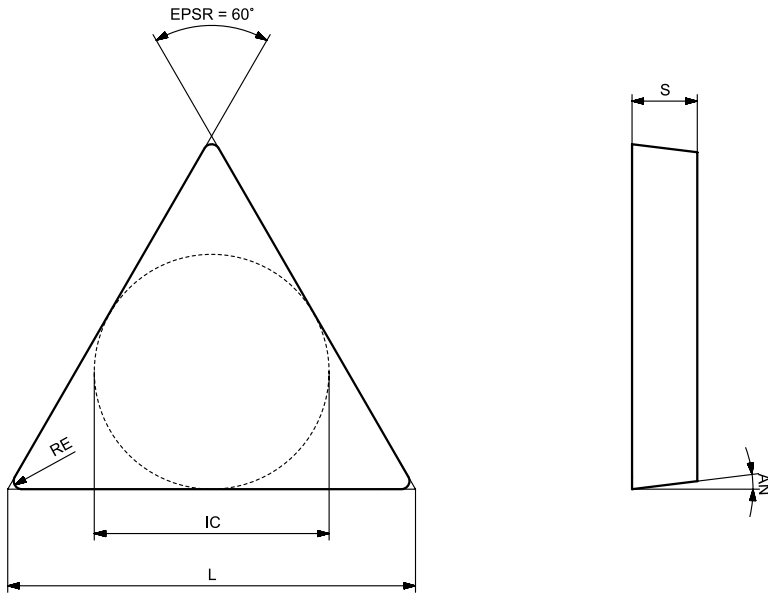


Figure 5.27: Depiction of a Triangular Insert

Additional remarks:

- 1) EPSR is no free parameter since it equals 60° for all triangular inserts (special case of trigon shaped insert).

Symbol	Parameter Name	Type	Requirements
IC	InscribedCircleDiameter	Length	1 of 2 Non-Optional with L
L	CuttingEdgeLength	Length	1 of 2 Non-Optional with IC
RE	CornerRadius	Length	Required
AN	ClearanceAngleMajor	Angle	Optional
S	InsertThickness	Length	Required

5.7.3 Trigon Insert

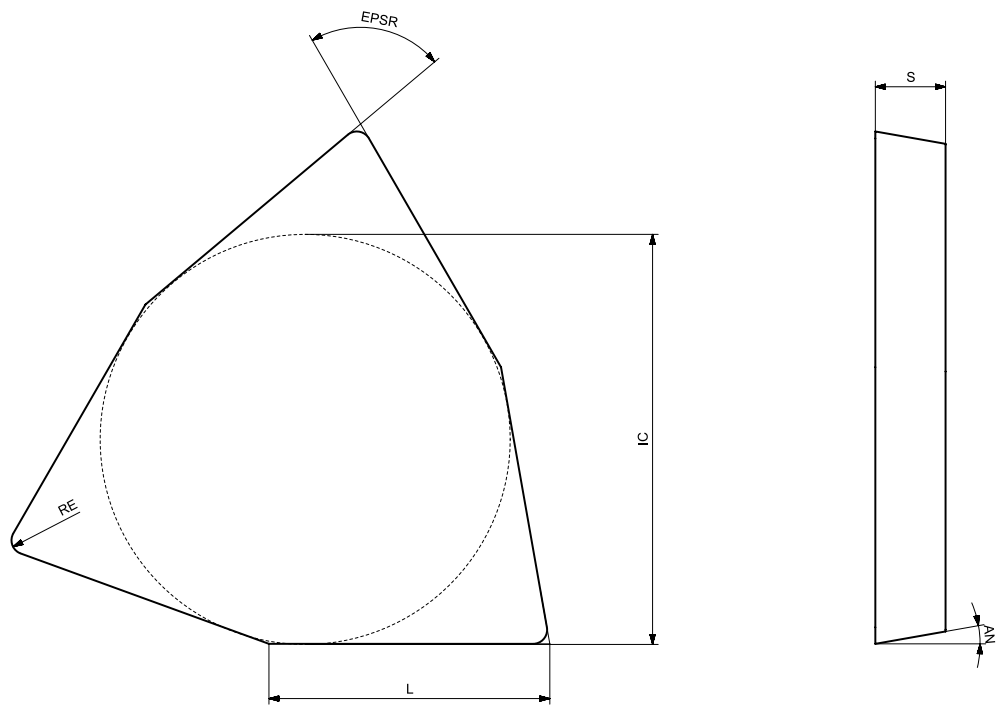


Figure 5.28: Depiction of a Trigon Insert

Symbol	Parameter Name	Type	Requirements
IC	InscribedCircleDiameter	Length	1 of 2 Non-Optional with L
L	CuttingEdgeLength	Length	1 of 2 Non-Optional with IC
RE	CornerRadius	Length	Required
EPSR	InsertIncludedAngle	Angle	Required
AN	ClearanceAngleMajor	Angle	Optional
S	InsertThickness	Length	Required

5.7.4 Round Insert

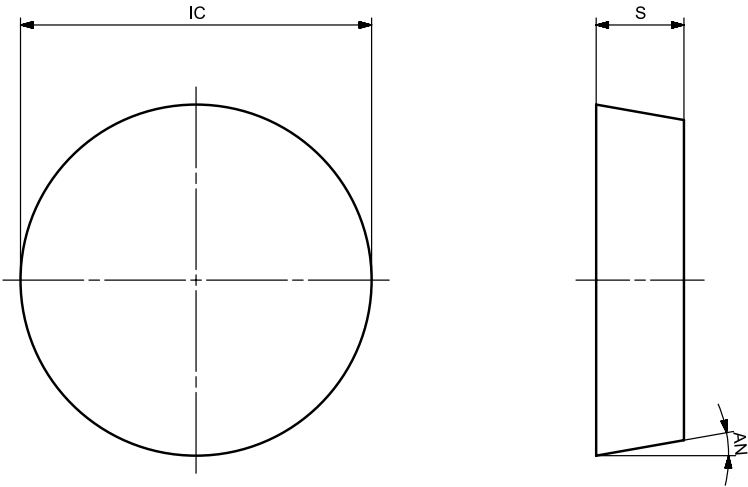


Figure 5.29: Depiction of a Round Insert

Symbol	Parameter Name	Type	Requirements
IC	InscribedCircleDiameter	Length	Required
AN	ClearanceAngleMajor	Angle	Optional
S	InsertThickness	Length	Required

5.7.5 Rhombic Insert

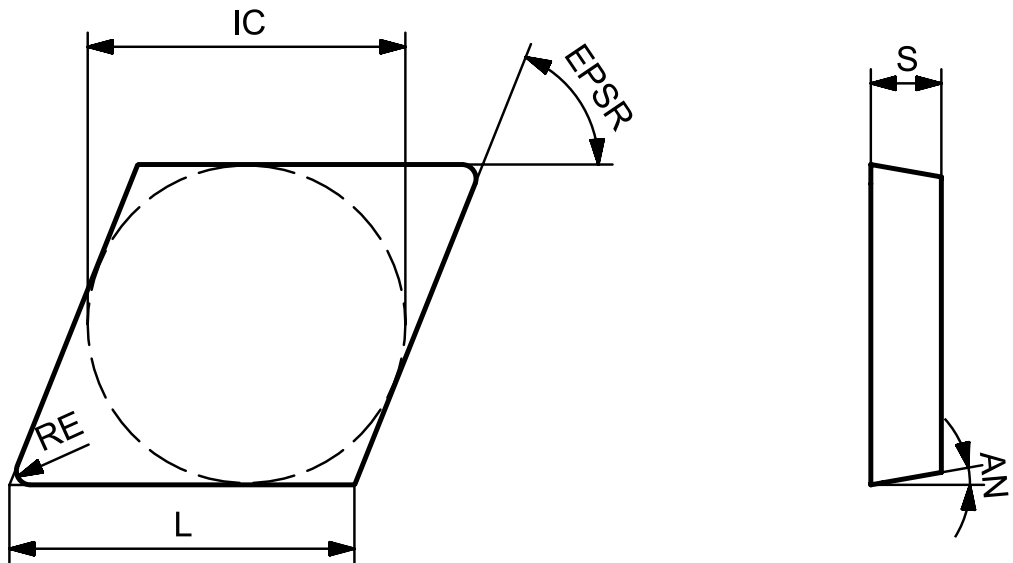


Figure 5.30: Depiction of a Rhombic Insert

Symbol	Parameter Name	Type	Requirements
IC	InscribedCircleDiameter	Length	1 of 2 Non-Optional with L
L	CuttingEdgeLength	Length	1 of 2 Non-Optional with IC
EPSR	InsertIncludedAngle	Angle	Required
RE	CornerRadius	Length	Required
AN	ClearanceAngleMajor	Angle	Optional
S	InsertThickness	Length	Required

5.7.6 Square Insert

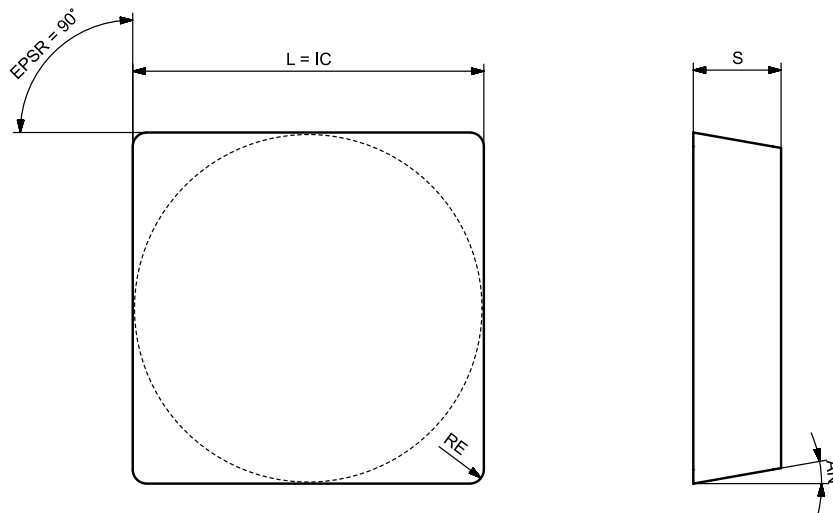


Figure 5.31: Depiction of a Square Insert

Additional remarks:

- 1) EPSR is no free parameter since it equals 90° for all square inserts (special case of rhombic shaped insert).

Symbol	Parameter Name	Type	Requirements
IC	InscribedCircleDiameter	Length	1 of 2 Non-Optional with L
L	CuttingEdgeLength	Length	1 of 2 Non-Optional with IC
RE	CornerRadius	Length	Required
AN	ClearanceAngleMajor	Angle	Optional
S	InsertThickness	Length	Required

5.7.7 Pentagonal Insert

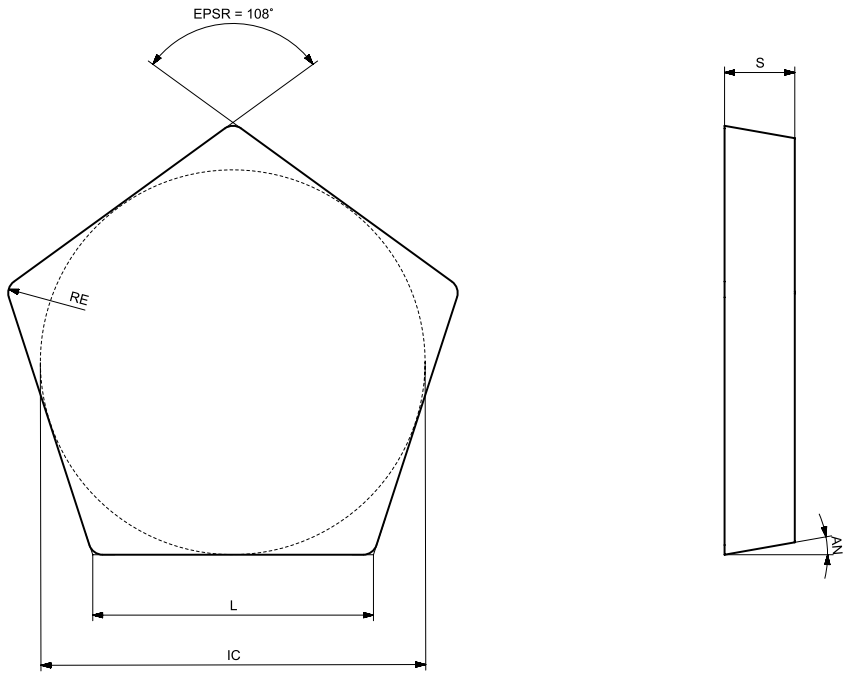


Figure 5.32: Depiction of a Pentagonal Insert

Additional remarks:

- 1) EPSR is no free parameter since it equals 108° for all pentagonal inserts.

Symbol	Parameter Name	Type	Requirements
IC	InscribedCircleDiameter	Length	1 of 2 Non-Optional with L
L	CuttingEdgeLength	Length	1 of 2 Non-Optional with IC
RE	CornerRadius	Length	Required
AN	ClearanceAngleMajor	Angle	Optional
S	InsertThickness	Length	Required

5.7.8 Hexagonal Insert

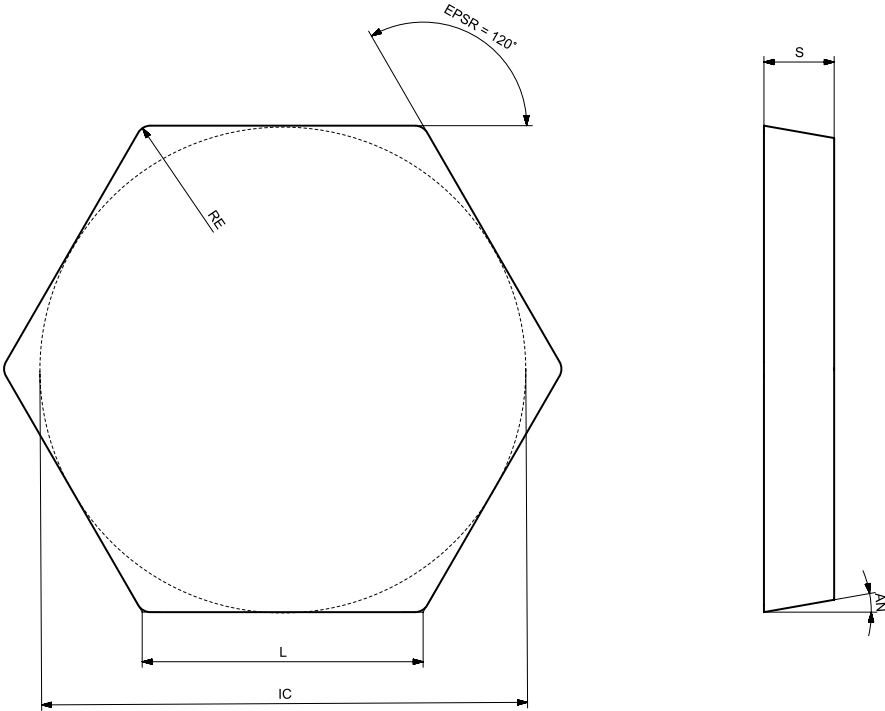


Figure 5.33: Depiction of a Hexagonal Insert

Additional remarks:

- 1) EPSR is no free parameter since it equals 120° for all hexagonal inserts.

Symbol	Parameter Name	Type	Requirements
IC	InscribedCircleDiameter	Length	1 of 2 Non-Optional with L
L	CuttingEdgeLength	Length	1 of 2 Non-Optional with IC
RE	CornerRadius	Length	Required
AN	ClearanceAngleMajor	Angle	Optional
S	InsertThickness	Length	Required

5.7.9 Octagonal Insert

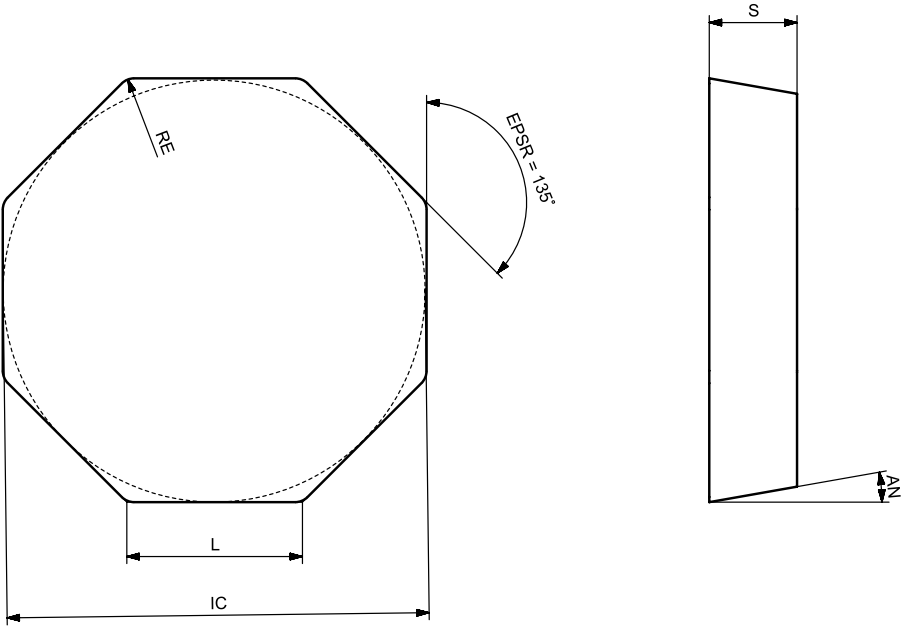


Figure 5.34: Depiction of a Octagonal Insert

Additional remarks:

- 1) EPSR is no free parameter since it equals 135° for all octagonal inserts.

Symbol	Parameter Name	Type	Requirements
IC	InscribedCircleDiameter	Length	1 of 2 Non-Optional with L
L	CuttingEdgeLength	Length	1 of 2 Non-Optional with IC
RE	CornerRadius	Length	Required
AN	ClearanceAngleMajor	Angle	Optional
S	InsertThickness	Length	Required

5.8 Other Inserts

5.8.1 Kite Insert

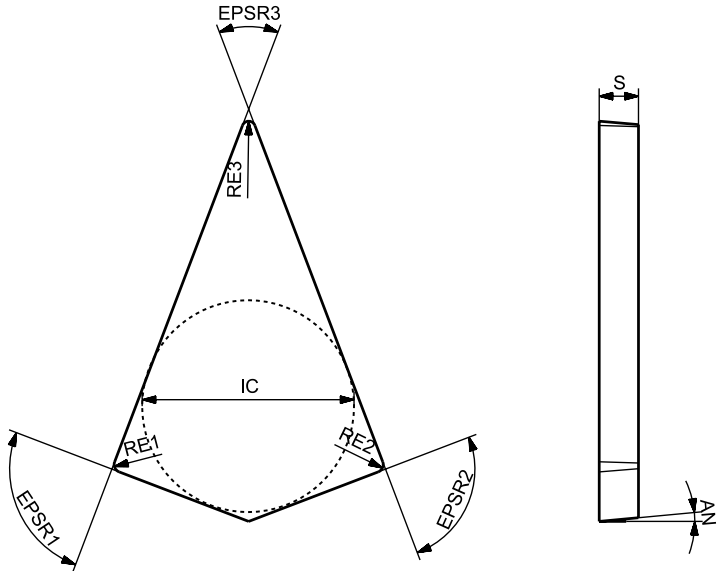


Figure 5.35: Depiction of a Kite Insert

Additional remarks:

- 1) If RE2 or RE3 are not given, RE1 is used.
- 2) If only one of EPSR1 and EPSR2 is given, symmetry is assumed ($\text{EPSR1} = \text{EPSR2}$).

Symbol	Parameter Name	Type	Requirements
IC	InscribedCircleDiameter	Length	Required
EPSR1	InsertIncludedAngle1	Angle	1 of 2 Non-Optional with EPSR2
EPSR2	InsertIncludedAngle2	Angle	1 of 2 Non-Optional with EPSR1
EPSR3	InsertIncludedAngle3	Angle	Required
RE1	CornerRadius1	Length	Required
RE2	CornerRadius2	Length	Optional
RE3	CornerRadius3	Length	Optional
S	InsertThickness	Length	Required
AN	ClearanceAngleMajor	Angle	Optional