ISO/TC 184/SC 4/WG 15 "Digital manufacturing"
Convenorship: **ANSI**
Convenor: **Hardwick Martin Dr**

20240328_ap238e4_cutting_tool_definition_and_usage

Document type	Related content	Document date	Expected action
Meeting / Working documents for discussion	Meeting: Renton (United States) 11 Mar 2024 Project: ISO/AWI 10303-238	2024-03-28	**INFO**

Replaces: N 255 AP238 Edition 4 Draft of CD model for cutting tool definition and usage

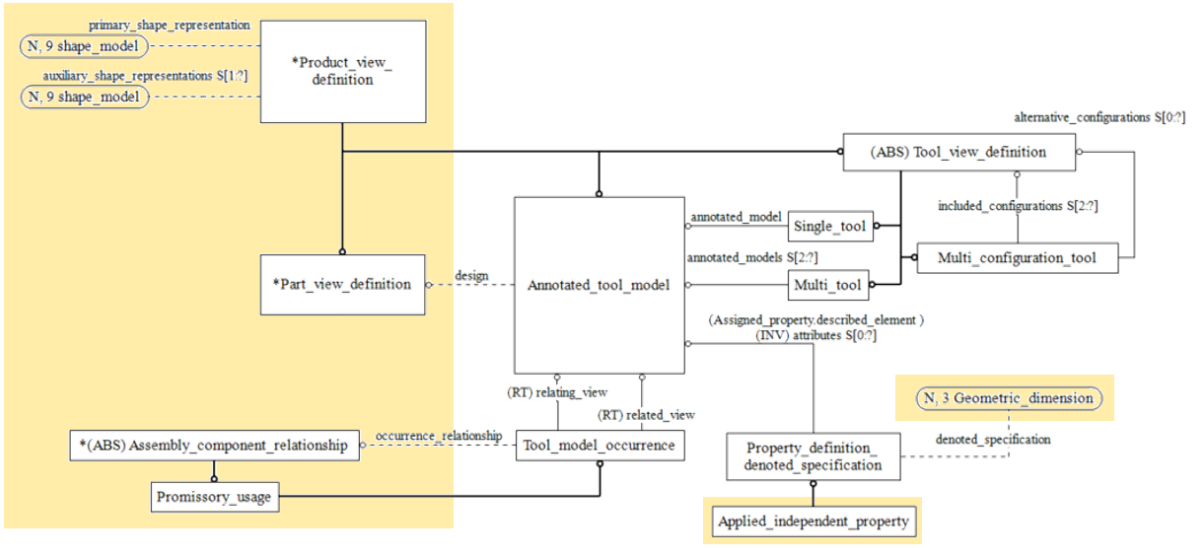
Description

Cutting tool definition and usage after editing in Renton.

AP238 Extension for cutting tool assembly and cutting recommendation

This document describes the ARM/AIM mappings for an AP238 extension for cutting tool assemblies and cutting recommendations. This extension gives support for tool data in annotated tool models, cutting process related characteristics of workpiece material and chip characterization, and process planning related characteristics of machining operations.

1. Application Objects



1.1. Tool_view_definition

A Tool_view_definition is a type of Product_view_definition. In the set of annotated_models the referenced detailed_designs are the parts of the tool definition.

```
ENTITY Tool_view_definition
ABSTRACT SUPERTYPE
SUBTYPE OF (Product_view_definition);
END_ENTITY;
```

1.2. Single_tool

A Single_tool is a type of Tool_view_definition a single tool specification.

```
ENTITY Single_tool
SUBTYPE OF (Tool_view_definition);
  annotated_model : Annotated_tool_model;
END_ENTITY;
```

1.2.1. annotated_model

The tool specification.

1.3. Multi_tool

A Multi_tool is a type of Tool_view_definition with two or more Annotated_tool_models. In the set of annotated_models all share the same detailed_design. A Multi_tool is a single product, possibly an assembly, that has more than one tool specification.

EXAMPLE 1 A multi tool with indexable inserts, a single tool body and three tool specifications (two turning tool and one milling tool), see Figure 1.

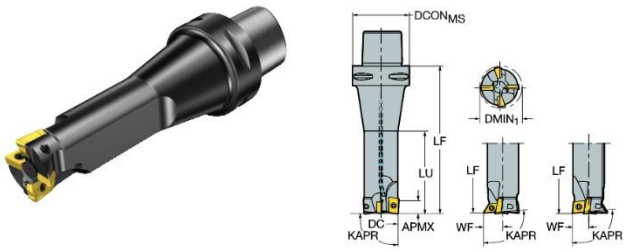


Figure 1 – Multi tool with indexable inserts.

EXAMPLE 2 A multi tool with non-indexable cutting edges and three tool specifications (one threading tool, one drill tool and one turning tool), see Figure 2.

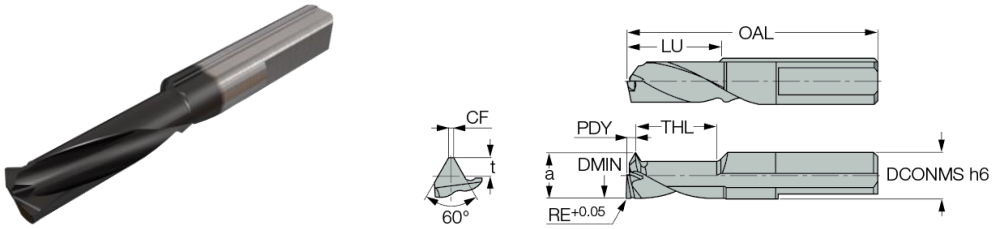


Figure 2 – Multi tool with non-indexable cutting edges.

EXAMPLE 3 A multi tool created by assembly of tool components and four tool specifications (two turning tools, one grooving tool and one threading tool), see Figure 3.

Figure 3 – Multi tool, as a result from assembling tool components.

```
ENTITY Multi_tool
SUBTYPE OF (Tool_view_definition);
  annotated_models : SET [2:?] OF Annotated_tool_model;
--  WR1: not more than one Part_view_definition referenced by the set of
Annotated_tool_models
END_ENTITY;
```

1.3.1. annotated_models

The set of tool specifications.

Formal proposition:
WR1: not more than one Part_view_definition referenced by the set of Annotated_tool_models.

1.4. Multi_configuration_tool

A Multi_configuration_tool is a type of Tool_view_definition with two or more specified tool configurations. A tool configuration is a Single_tool, Multi_tool or a sub-configuration.

```
ENTITY Multi_configuration_tool
SUBTYPE OF (Tool_view_definition);
  included_configurations : SET [1:?] OF Tool_view_definition;
  alternative_configurations : SET [1:?] OF Tool_view_definition;
END_ENTITY;
```

1.4.1. included_configurations

Set of Tool_view_specifications of tools with parts included.

1.4.2. alternative_configurations

Set of Tool_view_specifications of tools with part not included.

EXAMPLE 1 A multi configuration tool with two specified tool configurations included, both as single tools (one grooving tool and one threading tool), see Figure 4.

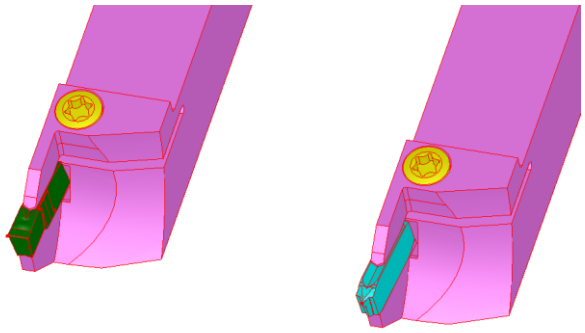


Figure 4 – Multi configuration tool with two specified tool configurations.

EXAMPLE 2 A multi configuration tool with one specified tool configuration included and one alternative configuration not included (different clamp set and insert shim), see Figure 5.

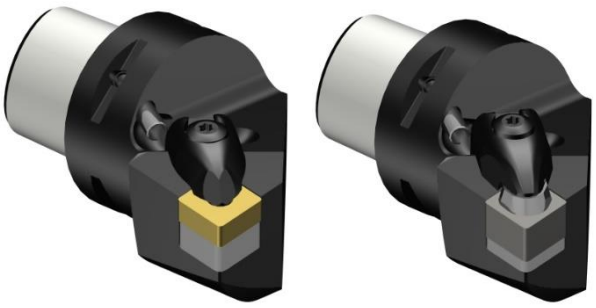


Figure 5 – Multi configuration tool with two specified tool configurations, one included and one alternative configuration not included.

1.5. Annotated_tool_model

An Annotated_tool_model is a type of Product_view_definition and represent attributes about a tool as an annotated model in accordance with ISO 16792. The annotation may state if the referenced design model is an auxiliary part, for instance a Master insert. Auxiliary parts are only used in a tool specification and will not be realized as a physical part. The primary shape representation of the design represents the detailed design model in accordance with ISO 13399-80. The auxiliary shape representations of the design represents basic design models in accordance with ISO 13399-80.

```
ENTITY Annotated_tool_model
SUBTYPE OF (Product_view_definition);
  design : OPTIONAL Part_view_definition;
INVERSE
  attributes : SET [0:?] OF Property_definition_denoted_specification for
described_element;
END_ENTITY;
```

1.5.1. design

The design part.

1.6. Tool_model_occurrence

A Tool_model_occurrence is a type of Promissory_usage and represent an Annotated_tool_model as a component of an assembly Annotated_tool_model.

```
ENTITY Tool_model_occurrence
SUBTYPE OF (Promissory_usage);
  SELF\Product_occurrence_definition_relationship.relating_view :
Annotated_tool_model;
  SELF\Product_occurrence_definition_relationship.related_view :
Annotated_tool_model;
  occurrence_relationship : OPTIONAL Assembly_component_relationship;
END_ENTITY;
```

1.6.1. relating_view

The tool assembly.

1.6.2. related_view

The tool component.

1.6.3. occurrence_relationship

Relationship between the tool component occurrence and the design component occurrence.

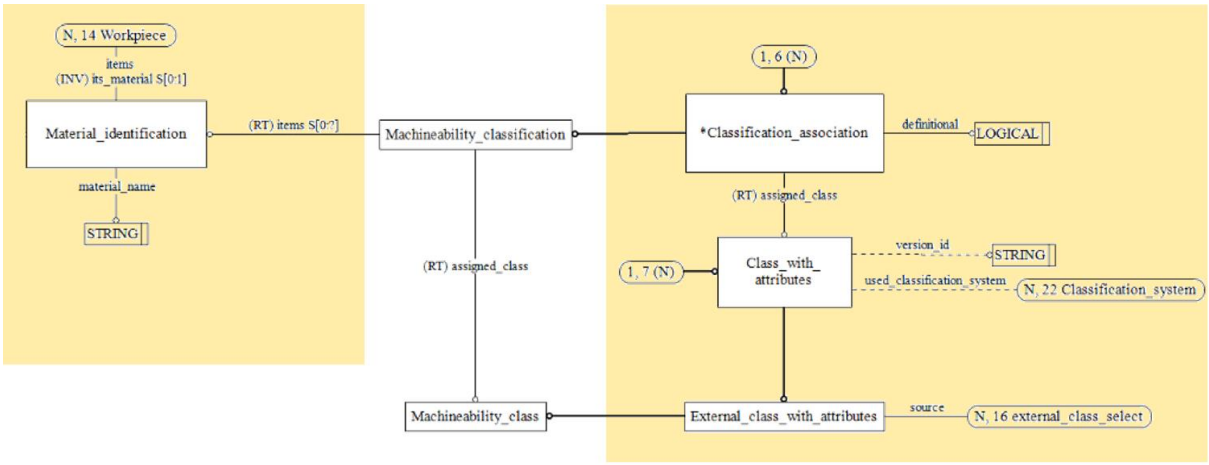
1.7. Property_definition_denoted_specification

A Property_definition_denoted_specification is a type of Applied_independent_property.

```
ENTITY Property_definition_denoted_specification
SUBTYPE OF (Applied_independent_property);
  denoted_specification : OPTIONAL denoted_specification_select;
END_ENTITY;
```

1.7.1. denoted_specification

The denoted geometric product specification data.



1.8. Machineability_class

A Machineability_class is a type of External_class_with_attributes. The members of a Machineability_class has equal characteristics in cutting. The members may have different characteristics in other aspects, for instance in material composition and heat treatment.

```
ENTITY Machineability_class
  SUBTYPE OF (External_class_with_attributes);
END_ENTITY;
```

1.9. Machineability_classification

A Machineability_classification is a type of Classification_association. It associates a machineability_class with Material_identifications.

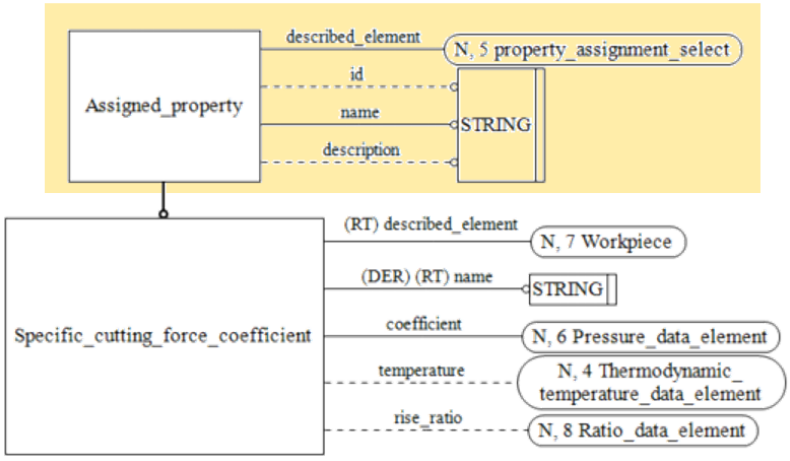
```
ENTITY Machineability_classification
  SUBTYPE OF (Classification_association);
  SELF\Classification_assignment.items : SET [0:?] OF
material_identification;
  SELF\Classification_assignment.assigned_class : Machineability_class;
END_ENTITY;
```

1.9.1. items

An attribute inherited from the Classification_association redeclared as Material_identifications.

1.9.2. assigned_class

An attribute inherited from the Classification_association redeclared as Machineability_class.



1.10. Specific_cutting_force_coefficient

Force per area for a chip thickness of 1 mm (0.0394 inch) in tangential direction. A specific material may different specific cutting force coefficient at different shear-zone temperatures.

```
ENTITY Specific_cutting_force_coefficient
  SUBTYPE OF (Assigned_property);
  SELF\Assigned_property.described_element : Workpiece;
  coefficient : Pressure_data_element;
  temperature : OPTIONAL Thermodynamic_temperature_data_element;
  rise_ratio : OPTIONAL Ratio_data_element;
DERIVE
  SELF\Assigned_property.name : STRING := 'specific cutting force
coefficient';
END_ENTITY;
```

1.10.1. coefficient

Measured in newton/square millimeters (N/mm2) or pounds/square inch (lbs/in2). Traditionally named k_c 1.1.

1.10.2. temperature

Shear-zone temperature applicable for the specific cutting force coefficient.

1.10.3. rise_ratio

Rise in specific cutting force as a function of reduced chip thickness, as illustrated in Figure 6.

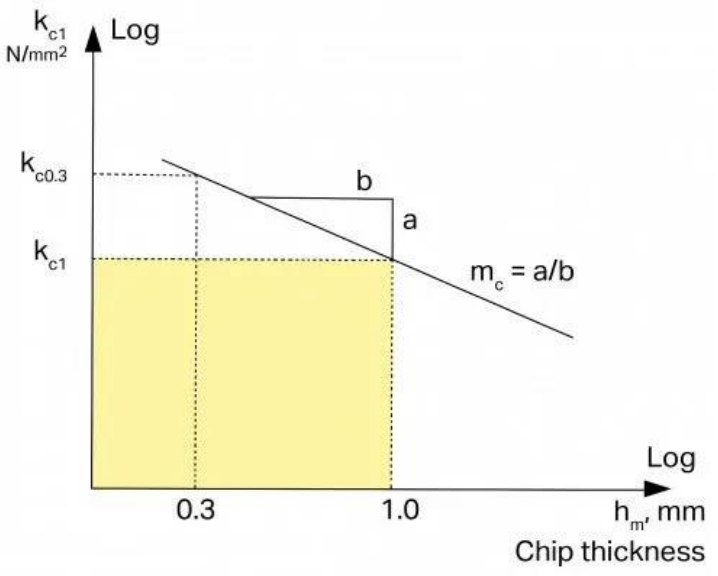


Figure 6 – Specific cutting force as a function of chip thickness. Rise ratio = m_c.

EXAMPLE The coefficient used in calculation formulas for power, torque and cutting force, see Figure 7.

Specific cutting forces

$$k_c = k_{c1} \times \left(\frac{1}{h_m}\right)^{m_c} \times \left(1 - \frac{\gamma_o}{100}\right)$$

Net power, kW

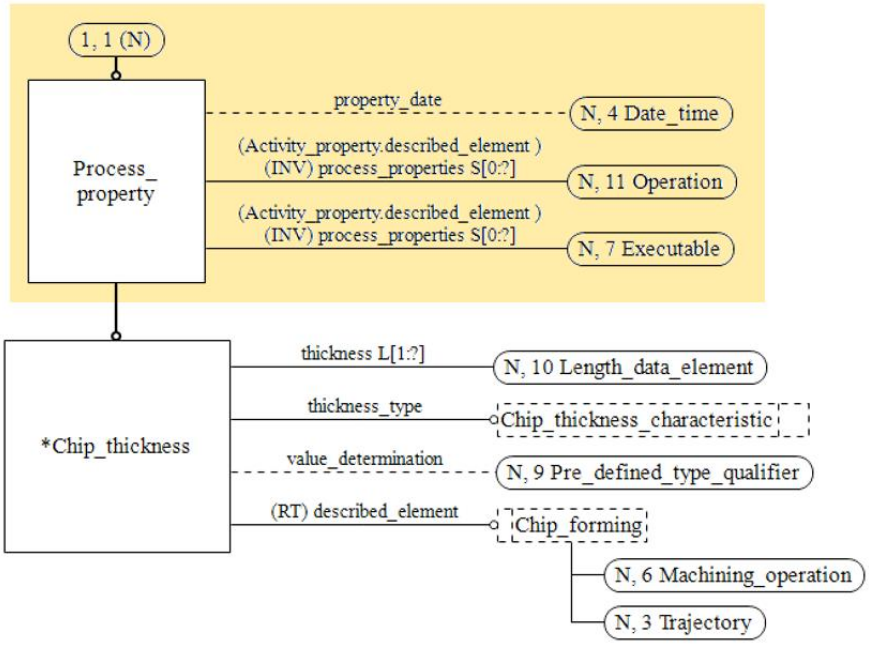
$$P_c = \frac{a_e \times a_p \times v_f \times k_c}{60 \times 10^6}$$

Torque, Nm

$$M_c = \frac{P_c \times 30 \times 10^3}{\pi \times n}$$

	Designation / definition	
a_e	Working engagement	mm
a_p	Cutting depth	mm
n	Spindle speed	rpm
v_f	Table feed	mm/min
h_m	Average chip thickness	mm
k_c	Specific cutting force	N/mm²
P_c	Net power	kW
M_c	Torque	Nm
m_c	Raise ratio	
γ_0	Rake angle	degree

Figure 7 – Formulas for calculation of specific cutting force, net power and torque.



1.11. Chip_thickness

Thickness of a chip before it is cut. There are different types of chip thickness characterizations of a cutting process. The chip thickness measure can be used in calculation of cutting forces and tool life estimation. Chip thickness for a machining operation is the average value during the time for the cutting edge in cut engagement. Chip thickness for a trajectory shall be defined in each point of the Trajectory.

```
ENTITY Chip_thickness
  SUBTYPE OF (Process_property);
  SELF\Activity_property.described_element : Chip_forming;
  thickness : LIST [1:?] OF Length_data_element;
  thickness_type: Chip_thickness_characteristic;
  value_determination : OPTIONAL Pre_defined_type_qualifier;
WHERE
  WR1: NOT (SELF.thickness_type =
Chip_thickness_characteristic.operation_equivalent) OR (1 =
SIZEOF(thickness));
END_ENTITY;

TYPE Chip_forming = SELECT (
   Machining_operation, Trajectory);
END_TYPE;

TYPE Chip_thickness_characteristic = ENUMERATION OF (max, average,
area_equivalent, volume_equivalent, operation_equivalent);
END_TYPE;
```

1.11.1. described_element

The machining operation or trajectory with chip forming process.

1.11.2. thickness

The thickness measure value.

1.11.3. thickness_type

Type of chip thickness characterisation. Examples in Figure 8.

Enumerated item definitions:

max: maximum thickness of the chip.

average: average thickness of the chip. Applicable for chip with varying thickness.

area_equivalent: width of a rectangle with area equivalent to the actual cross section area of the chip. The measure is used to compensate for the radius (Woxén, R., 1932, Ståhl J-E. and Schultheiss F., 2012).

volume_equivalent: width of a rectangular cuboid with volume equivalent to the actual volume of the chip. The measure is used to compensate for the radius and varying thickness (Hägglund, S., 2013).

operation_equivalent: thickness of a chip from an operation that is equivalent to a varying chip thickness in the actual operation. Equivalence shall be in the aspect of tool life and may be calculated in detail or estimated by the average over time. This type is only applicable for machining_operation as the described element.

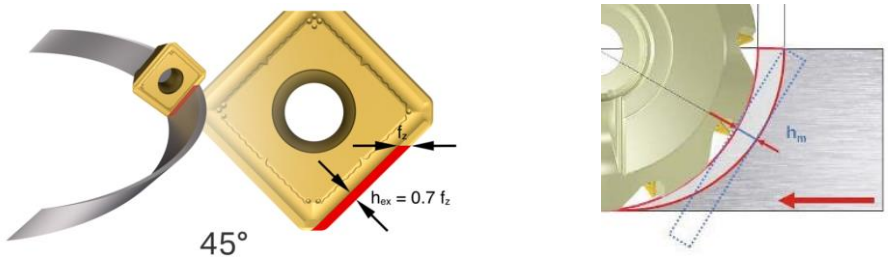


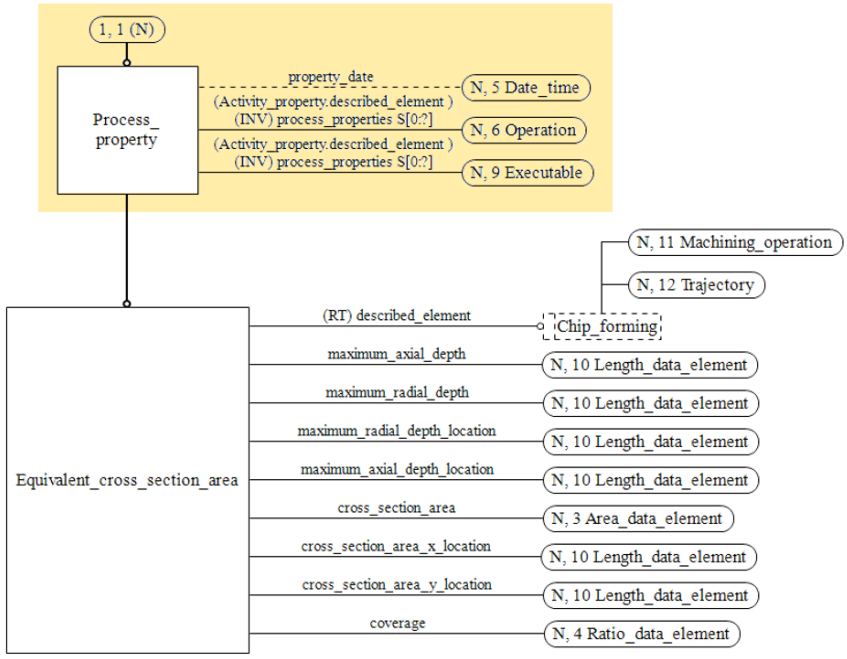
Figure 8 – Chip thickness in milling.

1.11.4. value_determination

Value type qualifier.

Formal proposition:

WR1: If the thickness type is operation_equivalent then there is only one thickness value.



1.12. Equivalent_cross_section_area

Material removal cross section area that is equivalent to a varying material removal cross section of a Trajectory. Equivalence shall be in the aspect of cut engagement time. The cross section is specified by seven attributes, each with a corresponding cross section area parameter defined in the Trajectory application object.

```
ENTITY Equivalent_cross_section_area
  SUBTYPE OF (Process_property);
  SELF\Activity_property.described_element : Chip_forming;
  maximum_axial_depth : Length_data_element; -- ADmax
  maximum_radial_depth : Length_data_element; -- RDmax
  maximum_radial_depth_location : Length_data_element; -- Xmaxofs
  maximum_axial_depth_location : Length_data_element; -- Ymaxofs
  cross_section_area : Area_data_element; -- CSA
  cross_section_area_x_location : Length_data_element; -- XCGofs
  cross_section_area_y_location : Length_data_element; -- YCGofs
  coverage : Ratio_data_element;
END_ENTITY;
```

1.12.1. described_element

The Machining_operation or Trajectory with a chip forming process.

1.12.2. maximum_axial_depth

The maximum axial depth of the tool contact cross section, corresponding to the ADmax parameter.

1.12.3. maximum_radial_depth

The maximum radial depth of the tool contact cross section, corresponding to the RDmax parameter.

1.12.4. maximum_radial_depth_location

The location along the X axis where the maximum radial depth measure is located, corresponding to the Xmaxofs parameter.

1.12.5. maximum_axial_depth_location

The location along the Y axis where the maximum axial depth measure is located, corresponding to the Ymaxofs parameter.

1.12.6. cross_section_area

The total area of the tool contact cross section in the X-Y plane, corresponding to the CSA parameter.

1.12.7. cross_section_area_x_location

The location along the X axis of the centre of gravity of the tool contact cross section, corresponding to the XCGofs parameter.

1.12.8. cross_section_area_y_location

The location along the Y axis of the centre of gravity of the tool contact cross section, corresponding to the YCGofs parameter.

1.12.9. coverage

The extent of total cut engagement time of the described element which the cross section area is equivalent.

2. Mapping specification

2.1. TOOL_VIEW_DEFINITION

```
AIM element: product_definition
Source: 10303-41
product_definition
product_definition.formation ->
product_definition_formation
product_definition_formation.of_product ->
product <-
{ product_related_product_category.products[i]
product_related_product_category <=
product_category
product_category.name='tool model collection' }
```

2.2. SINGLE_TOOL

```
AIM element: NOT MAPPED

NOTE   The Single_tool application object is not mapped. Instead, the mapping goes
directly to the Annotated_tool_model.
```

2.3. MULTI_TOOL

```
AIM element: /SUPERTYPE(Tool_view_definition)/
```

2.3.1. tool_view_definition to annotated_tool_model (as annotated_model)

```
AIM element: PATH
product_definition
product_definition_or_reference = product_definition
product_definition_or_reference <-
product_definition_relationship.relating_product_definition
```

```
{ product_definition_relationship =>
product_definition_usage =>
assembly_component_usage =>
next_assembly_usage_occurrence }
product_definition_relationship.related_product_definition ->
product_definition_or_reference
product_definition_or_reference = product_definition
product_definition
```

2.4. MULTI_CONFIGURATION_TOOL

```
AIM element: /SUPERTYPE(Tool_view_definition)/
```

2.4.1. multi_configuration_tool to tool_view_definition (as included_configuration)

```
AIM element: PATH
product_definition
product_definition_or_reference = product_definition
product_definition_or_reference <-
product_definition_relationship.relating_product_definition
{ product_definition_relationship =>
product_definition_usage =>
assembly_component_usage =>
next_assembly_usage_occurrence
next_assembly_usage_occurrence = ' included configuration' }
product_definition_relationship.related_product_definition ->
product_definition_or_reference
product_definition_or_reference = product_definition
product_definition
```

2.4.2. multi_configuration_tool to tool_view_definition (as alternative_configuration)

```
AIM element: PATH
product_definition
product_definition_or_reference = product_definition
product_definition_or_reference <-
product_definition_relationship.relating_product_definition
{ product_definition_relationship =>
product_definition_usage =>
assembly_component_usage =>
next_assembly_usage_occurrence
next_assembly_usage_occurrence = ' alternative configuration' }
product_definition_relationship.related_product_definition ->
product_definition_or_reference
product_definition_or_reference = product_definition
product_definition
```

2.5. ANNOTATED_TOOL_MODEL

```
AIM element: product_definition
Source: 10303-41
product_definition
product_definition product_definition.formation ->
product_definition_formation
product_definition_formation.of_product ->
product <-
{ product_related_product_category.products[i]
product_related_product_category <=
product_category
```

```
product_category.name='annotated model' }
```

2.5.1. annotated_tool_model to part_view_definition (as design)

```
AIM element: PATH
product_definition
product_definition_or_reference = product_definition
product_definition_or_reference <-
product_definition_relationship.relating_product_definition
{ product_definition_relationship =>
product_definition_usage =>
assembly_component_usage =>
next_assembly_usage_occurrence }
product_definition_relationship.related_product_definition ->
product_definition_or_reference
product_definition_or_reference = product_definition
product_definition
```

2.6. TOOL_MODEL_OCCURRENCE

```
AIM element: promissory_usage_occurrence
Source: 10303-44
promissory_usage_occurrence <=
assembly_component_usage <=
product_definition_usage <=
product_definition_relationship
```

2.6.1. tool_model_occurrance to annotated_tool_model (as relating_view)

```
AIM element: PATH
promissory_usage_occurrence <=
assembly_component_usage <=
product_definition_usage <=
product_definition_relationship
product_definition_relationship.relating_product_definition ->
product_definition_or_reference
product_definition_or_reference = product_definition
product_definition
```

2.6.2. tool_model_occurrance to annotated_tool_model (as related_view)

```
AIM element: PATH
promissory_usage_occurrence <=
assembly_component_usage <=
product_definition_usage <=
product_definition_relationship
product_definition_relationship.related_product_definition ->
product_definition_or_reference
product_definition_or_reference = product_definition
product_definition
```

2.6.3. tool_model_occurrance to tool_design_occurrance (as occurrence_relationship)

```
AIM element: PATH
promissory_usage_occurrence <-
product_definition_relationship_relationship.relating
product_definition_relationship_relationship
{ product_definition_relationship_relationship.name = 'tracking' }
product_definition_relationship_relationship.related ->
assembly_component_usage =>
```

```
( next_assembly_usage_occurrence )
( specified_higher_usage_occurrence )
```

2.7. PROPERTY_DEFINITION_DENOTED_SPECIFICATION

```
AIM element: /SUPERTYPE(Applied_independent_property)/
Source: 10303-41
```

2.7.1. property_definition_denoted_specification to Geometric_dimension (as denoted_specification)

```
AIM element: PATH
property_definition <-
generic_property_definition_select = property_definition
generic_property_definition_select <-
generic_property_relationship.related
generic_property_relationship
{ generic_property_relationship.name =  'denoted specification' }
generic_property_relationship.relating ->
( generic_property_definition_select = dimensional_location )
( generic_property_definition_select = dimensional_size )
```

2.8. MACHINEABILITY_CLASS

```
AIM element: /SUPERTYPE(External_class_with_attributes)/
```

2.9. MACHINEABILITY_CLASSIFICATION

```
AIM element: /SUPERTYPE(Classification_association)/
```

2.9.1. machineability_classification to material_identification (as items)

```
AIM element: PATH
applied_classification_assignment.items[i] ->
classification_item
classification_item = material_designation
material_designation
```

2.9.2. machineability_classification to machineability_class (as assigned_class)

```
AIM element: PATH
applied_classification_assignment <=
classification_assignment
classification_assignment.assigned_class -> class
class =>
externally_defined_class <=
externally_defined_item
```

2.10. SPECIFIC_CUTTING_FORCE_COEFFICIENT

```
AIM element: property_definition
Source: 10303-41
{property_definition.name = 'specific cutting force coefficient'}
property_definition <-
property_definition_representation.definition
property_definition_representation.used_representation ->
representation
```

2.10.1. specific_cutting_force_coefficient to Workpiece (as described_element)

```
AIM element: PATH
property_definition
property_definition.definition ->
characterized_definition
characterized_definition = characterized_product_definition
characterized_product_definition
characterized_product_definition = product_definition
product_definition
```

2.10.2. specific_cutting_force_coefficient to Pressure_data_element (as coefficient)

```
AIM element: PATH
representation
representation.items[i] ->
{ representation_item.name = 'coefficient' }
representation_item =>
measure_representation_item <=
measure_with_unit =>
pressure_measure_with_unit
```

2.10.3. specific_cutting_force_coefficient to thermodynamic_temperature_data_element (as temperature)

```
AIM element: PATH
representation
representation.items[i] ->
{ representation_item.name = temperature' }
representation_item =>
measure_representation_item <=
measure_with_unit =>
celsius_temperature_measure_with_unit
```

2.10.4. specific_cutting_force_coefficient to ratio_data_element (as rise_ratio)

```
AIM element: PATH
representation
representation.items[i] ->
{ representation_item.name = 'rise ratio' }
representation_item =>
measure_representation_item <=
measure_with_unit =>
ratio_measure_with_unit
```

2.11. CHIP_THICKNESS

```
AIM element: machining_process_property
Source: 10303-238
machining_process_property <=
action_property
{ action_property.name = 'chip thickness' }
action_property <-
action_property_representation.property
action_property_representation
action_property_representation.representation ->
representation
```

2.11.1. chip_thickness to Machining_operation (as described_element)

```
AIM element: PATH
machining_process_property <=
action_property
action_property.definition ->
characterized_action_definition
characterized_action_definition = action_method
action_method =>
machining_operation
```

2.11.2. chip_thickness to Trajectory (as described_element)

```
AIM element: PATH
machining_process_property <=
action_property
action_property.definition ->
characterized_action_definition
characterized_action_definition = action_method
action_method =>
machining_toolpath
```

2.11.3. thickness

```
AIM element: length_measure_with_unit
Source: 10303-41
machining_process_property <=
action_property <-
action_property_representation.property
action_property_representation
action_property_representation.representation ->
representation
representation.items[1] ->
representation_item =>
compound_representation_item
compound_representation_item.item_element ->
compound_item_definition = list_representation_item
list_representation_item[i] ->
representation_item =>
measure_representation_item <=
measure_with_unit =>
length_measure_with_unit
```

2.11.4. chip_thickness to Chip_thickness_characteristic (as thickness_type)

```
AIM element: machining_process_property.name
Source 10303-238
machining_process_property <=
action_property
{ ( action_property.name = 'max' )
( action_property.name = 'average' )
( action_property.name = 'area equivalent' )
( action_property.name = 'volume equivalent' )
( action_property.name = 'operation equivalent' ) }
```

2.11.5. chip_thickness to Pre_defined_type_qualifier (as value_determination)

```
AIM element: type_qualifier
Source: 10303-45
machining_process_property <=
action_property <-
action_property_representation.property
action_property_representation
```

```
action_property_representation.representation ->
representation
representation.items[i] ->
representation_item =>
qualified_representation_item
qualified_representation_item.qualifiers[i] ->
value_qualifier = type_qualifier
type_qualifier
```

2.12. EQUIVALENT_CROSS_SECTION_AREA

```
AIM element: machining_process_property
Source: 10303-238
machining_process_property <=
action_property
{ action_property.name = ' equivalent cross section area' }
action_property <-
action_property_representation.property
action_property_representation
action_property_representation.representation ->
representation
```

2.12.1. equivalent cross section area to Machining_operation (as described_element)

```
AIM element: PATH
machining_process_property <=
action_property
action_property.definition ->
characterized_action_definition
characterized_action_definition = action_method
action_method =>
machining_operation
```

2.12.2. equivalent cross section area to Trajectory (as described_element)

```
AIM element: PATH
machining_process_property <=
action_property
action_property.definition ->
characterized_action_definition
characterized_action_definition = action_method
action_method =>
machining_toolpath
```

2.12.3. maximum_axial_depth

```
AIM element: length_measure_with_unit
Source: 10303-41
AIM element: PATH
representation
representation.items[i] ->
{ representation_item.name = 'maximum axial depth' }
representation_item =>
measure_representation_item <=
measure_with_unit =>
length_measure_with_unit
```

2.12.4. maximum_radial_depth

```
AIM element: length_measure_with_unit
Source: 10303-41
```

```
AIM element: PATH
representation
representation.items[i] ->
{ representation_item.name = 'maximum radial depth' }
representation_item =>
measure_representation_item <=
measure_with_unit =>
length_measure_with_unit
```

2.12.5. maximum_radial_depth_location

```
AIM element: length_measure_with_unit
Source: 10303-41
AIM element: PATH
representation
representation.items[i] ->
{ representation_item.name = 'maximum radial depth location' }
representation_item =>
measure_representation_item <=
measure_with_unit =>
length_measure_with_unit
```

2.12.6. maximum_axial_depth_location

```
AIM element: length_measure_with_unit
Source: 10303-41
AIM element: PATH
representation
representation.items[i] ->
{ representation_item.name = ' maximum_axial_depth_location' }
representation_item =>
measure_representation_item <=
measure_with_unit =>
length_measure_with_unit
```

2.12.7. cross_section_area

```
AIM element: area_measure_with_unit
Source: 10303-41
AIM element: PATH
representation
representation.items[i] ->
{ representation_item.name = 'cross section area' }
representation_item =>
measure_representation_item <=
measure_with_unit =>
area_measure_with_unit
```

2.12.8. cross_section_area_x_location

```
AIM element: length_measure_with_unit
Source: 10303-41
AIM element: PATH
representation
representation.items[i] ->
{ representation_item.name = 'cross section area x location' }
representation_item =>
measure_representation_item <=
measure_with_unit =>
length_measure_with_unit
```

2.12.9. cross_section_area_y_location

```
AIM element: length_measure_with_unit
Source: 10303-41
AIM element: PATH
representation
representation.items[i] ->
{ representation_item.name = 'cross section area y location' }
representation_item =>
measure_representation_item <=
measure_with_unit =>
length_measure_with_unit
```

2.12.10. coverage

```
AIM element: ratio_measure_with_unit
Source: 10303-41
AIM element: PATH
representation
representation.items[i] ->
{ representation_item.name = 'coverage' }
representation_item =>
measure_representation_item <=
measure_with_unit =>
ratio_measure_with_unit
```

3. AIM EXPRESS Additions

No AIM additions are identified.

4. Annotated examples additions

4.1. Example usage of Multi_tool

Add annotated example to Annex J representing a Multi tool.

4.2. Example usage of Machineability_classification

Add annotated example to Annex J representing:

- Machineability_classification
- Specific cutting force coefficient

4.3. Example usage of Process_property

Add annotated example to Annex J on process planning related characteristics of machining operations. Measures including qualifiers for CAM process properties:

- Estimated average force [N]
- Measured maximum torque [Nm]
- Calculated duration [s] (considering machine tool axis movement limits)

- Cutting tool wear [%] (time in cut divided by tool life)
- User defined strategy parameters (e.g. Sandvik Coromant CoroPlus OptiThreading™)

5. Minor corrections to current AP238 edition

Figure 2 and 3 text “maximim” should be “maximum”.

Group qualifier needed in return statement in function:

```
FUNCTION verify_ballnose_endmill_dimensions (
mt : machining_tool
): LOGICAL;
LOCAL
rads : SET OF REPRESENTATION_ITEM :=
get_tool_body_item (mt, 'edge radius');
dias : SET OF REPRESENTATION_ITEM :=
get_tool_body_item (mt, 'effective cutting diameter');
END_LOCAL;
RETURN ((0 = SIZEOF(rads)) OR
((1 = SIZEOF(rads)) AND
(1 = SIZEOF(dias)) AND
-- (rads[1].value_component = dias[1].value_component/2))
(rads[1]\representation_item\measure_representation_item.value_component =
dias[1]\representation_item\measure_representation_item.value_component/2))
);
END_FUNCTION; -- 10303-238: integrated_cnc_schema
```

Group qualifier needed in return statement in function:

```
FUNCTION verify_bullnose_endmill_dimensions (
mt : machining_tool
): LOGICAL;
LOCAL
rads : SET OF REPRESENTATION_ITEM :=
get_tool_body_item (mt, 'edge radius');
dias : SET OF REPRESENTATION_ITEM :=
get_tool_body_item (mt, 'effective cutting diameter');
END_LOCAL;
RETURN ((1 = SIZEOF(rads)) AND
(1 = SIZEOF(dias)) AND
-- (rads[1].value_component < dias[1].value_component/2)
(rads[1]\representation_item\measure_representation_item.value_component <
dias[1]\representation_item\measure_representation_item.value_component/2)
);
```

6. Change log

2024-03-27

- Added chip_thickness and Equivalent_cross_section_area to support tool life calculation.
- As agreed in WG15 Renton meeting:
  - Changed Specific_cutting_force_coefficient to be a subtype of Assigned_property.
  - Removed Product_view_twin, Assembly_component_twin, Product_view_twin_prototype, Product_view_twin_with_supplier_definition and Manufacturing_resource_view_twin.

    - Removed Annotated_model_definition, Design_model_definition, Detailed_tool_design, Tool_design_occurrence.

2024-03-12

- Changed definition of Product_view_twin and Product_view_twin_prototype with reference to ISO 23247-1.
- Added examples of Multi_tools and Multi_configuration_tools.
- Added example of calculation formulas based on specific cutting force coefficient.

2024-03-05

- Replaced Physical_tool_view (subtype of Product_as_individual_view) with Manufacturing_resource_view_twin to align with the proposed extension for Drill and Fill.
- Added_component_twin, Product_view_twin_prototype and Manufacturing_resource_view_twin.
- Changed Design_model_usage (subtype of Definitional_part_view_usage) to an attribute of Annotated_model_definition with mapping to next_assembly_usage_occurrence. The change is driven from discussion in WG15 Saratoga springs meeting 2023.
- Renamed Annotated_model_occurrence to Tool_model_occurence and changed it to subtype of Assembly_component_relationship.
- Renamed Design_model_occurrence to Tool_design_occurrence and changed it to subtype of Assembly_component_relationship.
- Changed Design_model_occurence_usage to an attribute of Tool_model_occurrence with mapping to product_definition_relationship_relationship.
- Added Tool_view_definition (subtype of Product_view_definition), Single_tool, Multi_tool, Multi_configuration_tool, Annotated_tool_model and Detailed_tool_design.
- Made Annotated_model_occurrence a subtype of Promissory_usage instead of Next_assembly_usage.
- Added specification for Annotated examples (section 4).

2023-10-26

- Replaced conceptual data structure with ARM entity definitions and EXPRESS diagrams.

2023-06-15

- Added conceptual data structure for cutting tool assemblies and cutting recommendations.

7. References

ISO/TC 184/SC 4/WG15 N251 AP238 Edition 4 Draft of CD model for Drill and Fill (document date 2024-03-04).

ISO 8000-116:2019 Master data: Exchange of quality identifiers: Application of ISO 8000-115 to authoritative legal entity identifiers.

ISO 16792:2021 Digital product definition data practices.

ISO 13399-80:2014 Creation and exchange of 3D models.

ISO 23247-1:2021 Digital twin framework for manufacturing – Overview and general principles.

Woxén, R., 1932 Theory and an equation for the life of lathe tools. Dissertation. Royal Swedish Academy of Engineering Sciences, Stockholm, Sweden.

Ståhl J-E. and Schultheiss F., 2012 Analytical calculation of the true equivalent chip thickness for cutting tools and its influence on the calculated tool life, Advanced Materials Research, Trans Tech Publ, 2012, pp. 80-86.

Hägglund, S. 2013 Methods and models for cutting data optimization, Chalmers University of Technology.