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

20240402_ap238e4_PBF

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	2024-04-03	**INFO**

Replaces: N 261 20240313_ap238e4_PBF

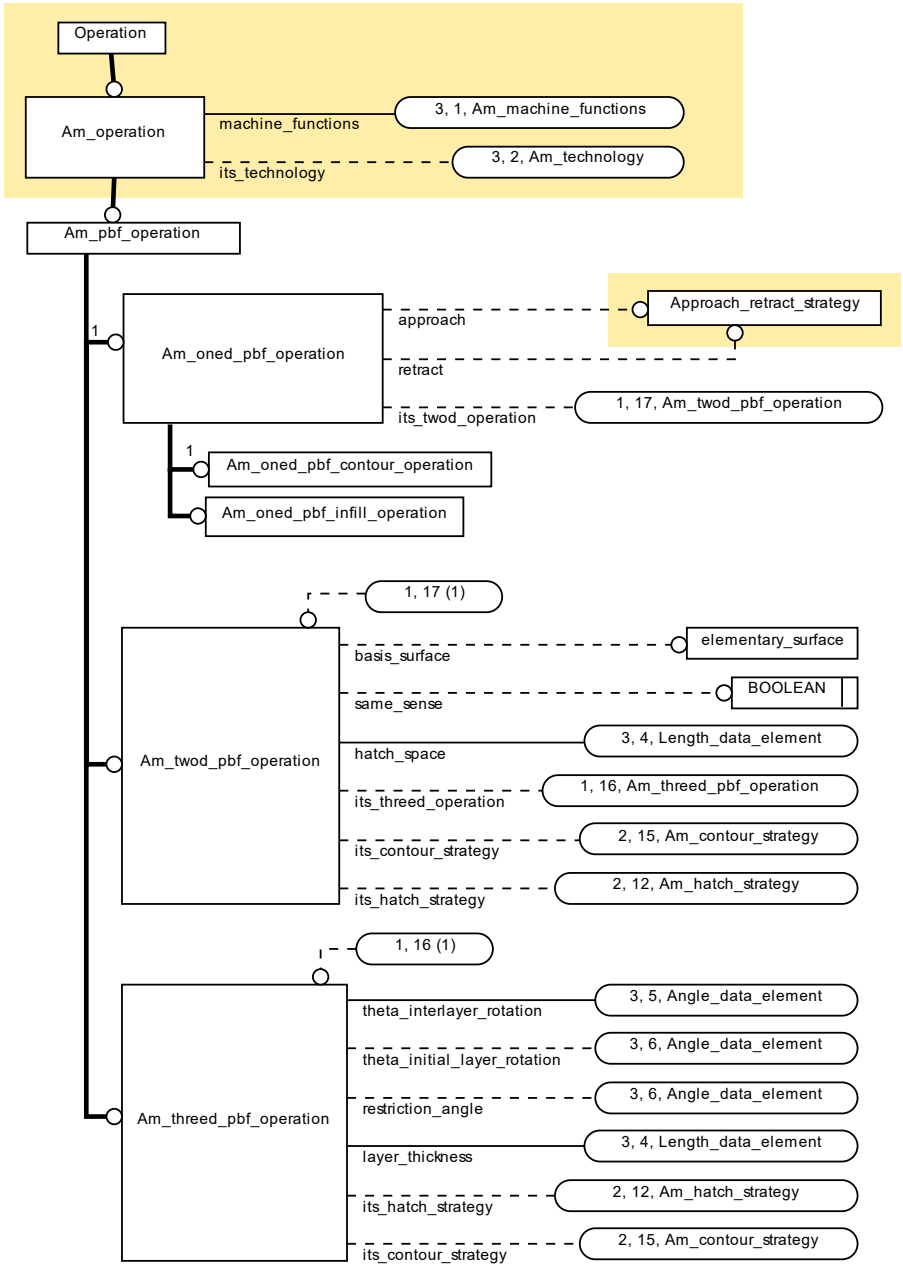
Description

AP238 E4 Powder bed fusion model after editing in Renton

AP238 Extension for Powder Bed Fusion

This document describes the ARM/AIM mappings for an AP238 extension for the automation of powder bed fusion.

1 Application Objects



Powder Bed Fusion Operations

1.1 Am_pbf_operation

The Am_pbf_operation application object defines the machine functions and technology to be used in a powder bed fusion operation. The Am_pbf_operation application object inherits from the Am_operation as defined in ISO 14649-17 [1]:

```
ENTITY Am_pbf_operation
ABSTRACT SUPERTYPE OF (ONEOF (Am_oned_pbf_operation, Am_twod_pbf_operation,
Am_threed_pbf_operation))
SUBTYPE OF (Am_operation);
-- its_machine_functions: Am_machine_functions;    INHERITED FROM AM OPERATION
-- its_technology:        OPTIONAL Am_technology;  INHERITED FROM AM OPERATION
END_ENTITY;
```

1.2 Am_oned_pbf_operation

The Am_oned_operation defines a path for the laser. The operation may include approach and retract strategies for approaching and exiting the scan path. The operation may include a reference to the twod_pbf_operation that was used to generate this oned entity.

```
ENTITY Am_oned_pbf_operation
ABSTRACT SUPERTYPE OF (ONEOF (Am_oned_pbf_contour_operation,
Am_oned_pbf_infill_operation))
SUBTYPE OF (Am_pbf_operation);
   approach         : OPTIONAL Approach_retract_strategy;
   retract          : OPTIONAL Approach_retract_strategy;
   its_twod_operation     : OPTIONAL Am_twod_pbf_operation;
DERIVE
  scan_path: toolpath_list :=
      SELF\Operation.its_toolpath;
END_ENTITY;
```

Note: The scan path is inherited from the operation entity

1.2.1 approach

optional information for approaching the scan path.

1.2.2 retract

optional information for exiting the scan path.

1.2.3 its_twod_operaton

the twod_operaton used to generate this oned_operation.

1.3 Am_oned_pbf_contour_operation

The Am_oned_contour_operation defines a contour path for the laser. A contour path is used to make an edge.

```
ENTITY Am_oned_pbf_contour_operation
SUBTYPE OF (Am_oned_pbf_operation);
DERIVE
  contour_path: toolpath_list :=
      SELF\Operation.its_toolpath;
END_ENTITY;
```

NOTE: The contour path is inherited from the operation entity.

1.4 Am_oned_pbf_infill_operation

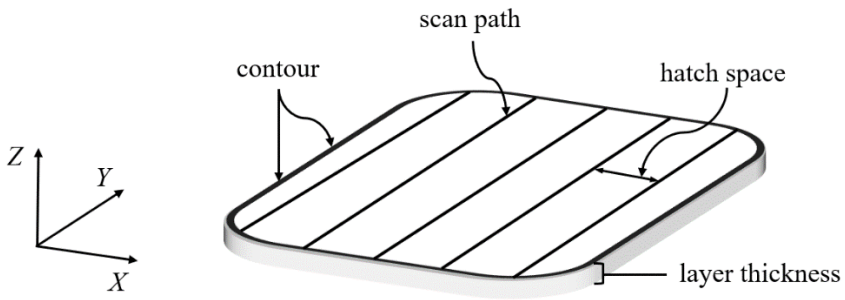
The Am_oned_infill_operation defines an infill path for the laser. An infill path is used to fill an area.

```
ENTITY Am_oned_pbf_infill_operation
SUBTYPE OF (Am_oned_pbf_operation);
DERIVE
  infill_path: toolpath_list :=
      SELF\Operation.its_toolpath;
END_ENTITY;
```

Note: The infill path is inherited from the operation entity.

1.5 Am_twod_pbf_operation

The Am_twod_operation defines information for generating Am_oned operations.




```
ENTITY Am_twod_pbf_operation
SUBTYPE OF (Am_pbf_operation);
   basis_surface    : OPTIONAL elementary_surface;
   same_sense       : OPTIONAL BOOLEAN;
   hatch_space            : Length_data_element;
```

```
   its_threed_operation    : OPTIONAL Am_threed_pbf_operation;
   its_contour_strategy    : OPTIONAL Am_contour_strategy;
   its_hatch_strategy      : OPTIONAL Am_hatch_strategy;
END_ENTITY;
```

1.5.1 basis_surface

the surface for the scan paths on this layer.

NOTE: If no surface is given then it shall be a Z plane at the height of the layer.

1.5.2 same_sense

false if the top is on the opposite side of the surface.

NOTE: the surface may be used elsewhere for other purposes

1.5.3 hatch_space

the distance between two consecutive in-fill paths in the in-fill.

1.5.4 its_threed_operaton

the threed_pbf_operaton used to generate this twod_pbf_operation.

1.5.5 its_hatch_strategy

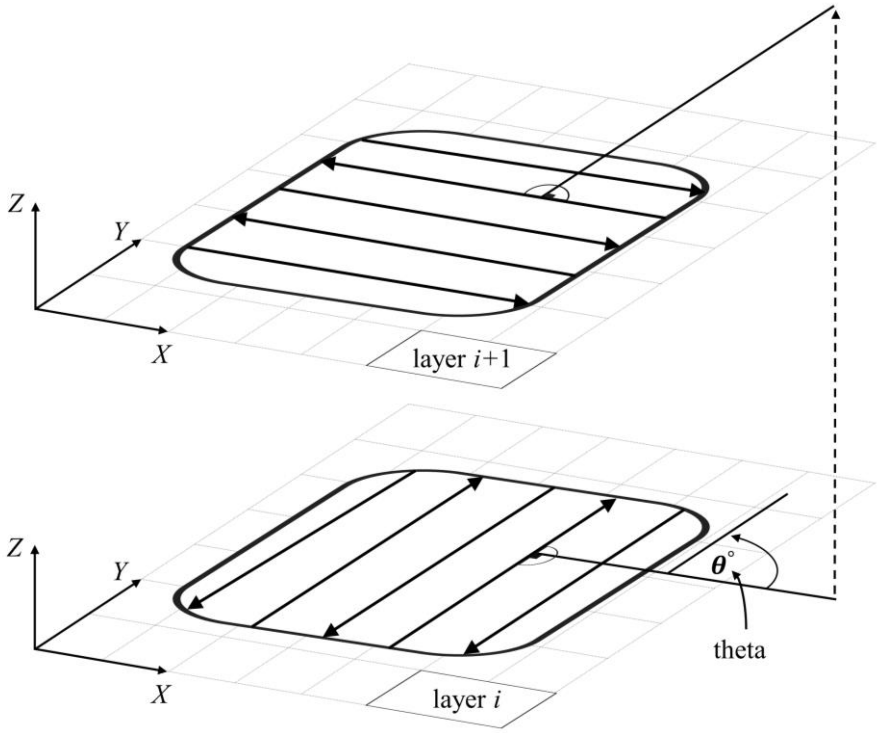
defines the strategy used to generate hatch paths for this operation.

1.5.6 its_contour_strategy

defines the strategy used to generate contour paths for this operation.

1.6 Am_threed_pbf_operation

The Am_threed_operation application object describes process parameters for generating Am_twod_operation application objects as a list of layers that together make a solid.




```
ENTITY Am_threed_pbf_operation
SUBTYPE OF (Am_pbf_operation);
   theta_interlayer_rotation     : Angle_data_element;
   theta_initial_layer_rotation  : OPTIONAL Angle_data_element;
   restriction_angle             : OPTIONAL Angle_data_element;
   layer_thickness               : Length_data_element;
   its_hatch_strategy            : OPTIONAL Am_hatch_strategy;
   its_contour_strategy          : OPTIONAL Am_contour_strategy;
END_ENTITY;
```

1.6.1 theta_interlayer_rotation

the rotation angle (θ) for the scan strategy of the current layer with respect to the scan strategy of the previous layer. The rotational direction of the scan strategy of a layer can be specified with a positive angle value indicating a counterclockwise rotation, or a negative angle value indicating a clockwise rotation.

1.6.2 theta_initial_layer_rotation

the rotation angle (θ) for the scan strategy of the first layer with respect to the coordinates of the build plate. The rotational direction of the scan strategy of the initial layer can be specified with a positive angle value indicating a counterclockwise rotation, or a negative angle value indicating a clockwise rotation.

1.6.3 restriction angle

Scan paths are not to be planed within this angle of the direction of the gas flow.

NOTE: Layers, islands or stripes that will make paths within this angle should be skipped.

1.6.4 layer_thickness

the thickness of each layer.

Note: the layer_thickness is used to generate the layers and may differ from the actual thickness as stored by the coordinates of each layer.

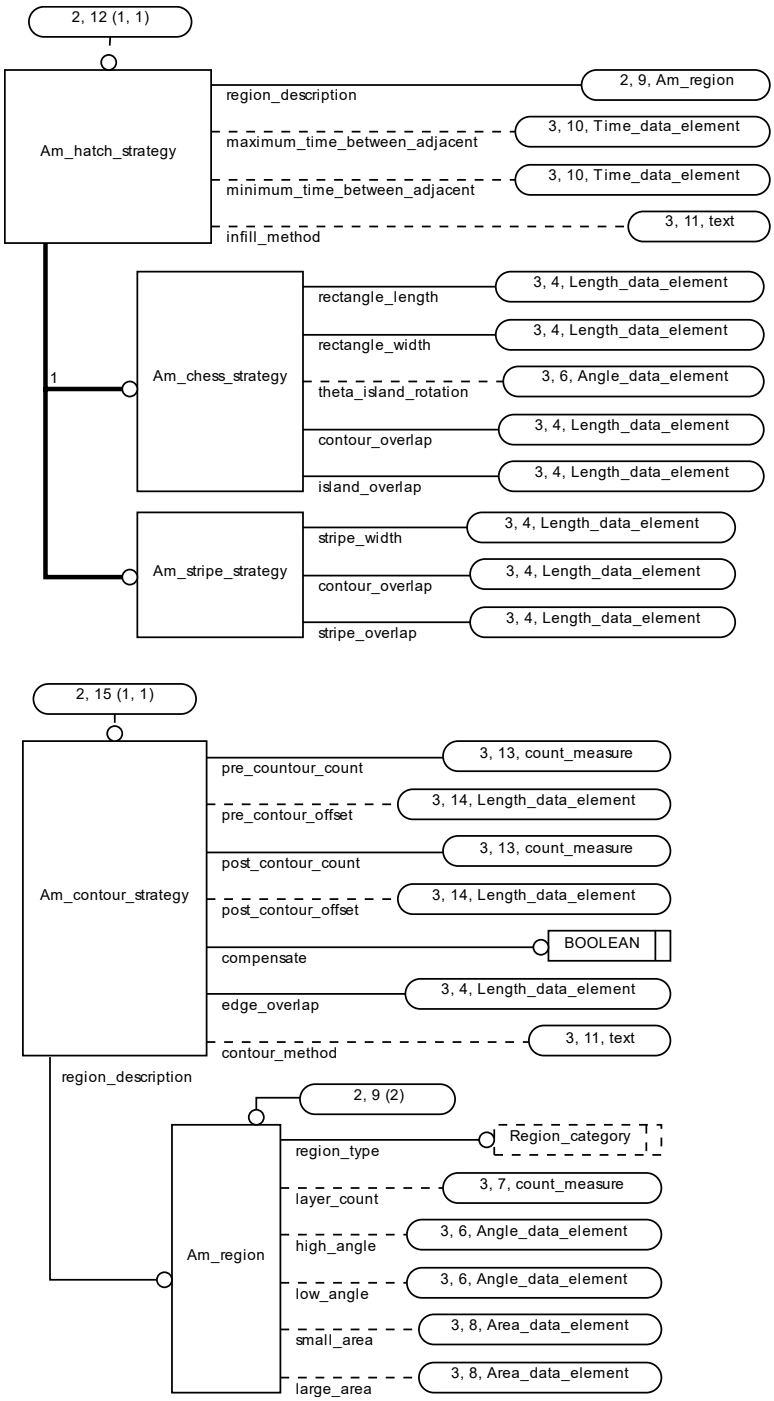
1.6.5 its_hatch_strategy

defines the strategy used to generate hatch paths for this operation.

NOTE: If there is a conflict between the strategy of an Am_twod_pbf_operation and the strategy of its associated Am_threed_pbf_operation then the strategy of the Am_twod operation shall take precedence.

1.6.6 its_contour_strategy

defines the strategy used to generate contour paths for this operation.



Powder Bed Fusion Strategies

1.7 Am_contour_strategy

The Am_contour_strategy application object defines a strategy for generating contour paths onto a layer.

```
ENTITY Am_contour_strategy;
   region_description     : Am_region;
   pre_countour_count     : count_measure;
   pre_contour_offset     : OPTIONAL Length_data_element;
   post_contour_count     : count_measure;
   post_contour_offset    : OPTIONAL Length_data_element;
   compensate       : BOOLEAN;
   edge_overlap           : Length_data_element;
   contour_method   : OPTIONAL text;
END_ENTITY;
```

1.7.1 region_description

a description of the region where a type of strategy applies.

1.7.2 pre_contour_count

the number of times to run the contour before hatching the in-fill.

1.7.3 pre_contour_offset

distance between consecutive pre_contours.

1.7.4 post_contour_count

the number of times to run the contour after hatching the in-fill.

1.7.5 post_contour_offset

distance between consecutive post_contours

1.7.6 compensate

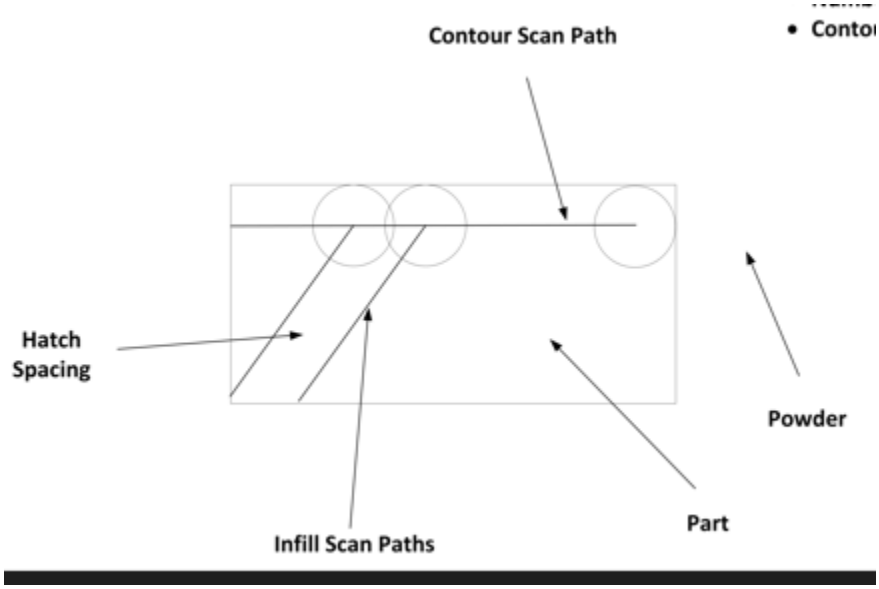
move the path of the contour so that the edge of the beam coincides with the edge of the part.

1.7.7 edge_overlap

move the path beyond the edge to ensure corners are completely filled.

NOTE: Moving the path beyond the edge ensures that all required material is scanned but maybe at the cost of scanning additional material beyond the edge. If the additional

material means the part tolerance will not be met, then the excess material can be removed by machining.



A compensated contour scan path that does not fuse material in the top right corner

1.7.8 contour_method

a textual summary of how contours are generated.

NOTE: The contour method may describe methods not included in the standard.

1.8 Am_region

The Am_region describes a zone on the part where a strategy is to be applied.

```
ENTITY Am_region;
   region_type            : Region_category;
   layer_count            : OPTIONAL count_measure;
   high_angle       : OPTIONAL Angle_data_element;
   low_angle        : OPTIONAL Angle_data_element;
   small_area       : OPTIONAL Area_data_element;
   large_area       : OPTIONAL Area_data_element;
END_ENTITY;

TYPE Region_category = ENUMERATION OF (core, upskin, downskin, future_hole, support,
small, large); END_TYPE;
```

1.8.1 region_category

the category of region where this strategy applies.

- core if this strategy applies to core regions of the part
- upskin if this strategy applies to regions near a top face of the part
- downskin if this strategy applies to regions near a bottom face of the part
- future_hole if this strategy applies to a feature that will be removed by machining
- support if this strategy applies to support structures
- large if this strategy applies to regions in the core that are large
- small if this strategy applies to regions in the core that are small

1.8.2 layer_count

if the strategy is being applied to a region that is close to a surface, then the number of layers where this strategy should apply.

1.8.3 high_angle

if the strategy is being applied to an upskin or downskin that the high value limit that any slope must meet to be classified as this type of skin.

1.8.4 low_angle

if the strategy is being applied to an upskin or downskin that the low value limit that any slope must meet to be classified as this type of skin.

1.8.5 large_area

if the strategy is being applied to an area in the core that needs special treatment because it is larger than normal.

1.8.6 small_area

if the strategy is being applied to an area in the core that needs special treatment because it is smaller than normal.

1.9 Am_hatch_strategy

The Am_hatch_strategy application object defines a strategy for generating hatch paths onto a layer.

```
ENTITY Am_hatch_strategy
ABSTRACT SUPERTYPE OF (ONEOF (Am_stripe_strategy, Am_chess_strategy));
   region_description            : Am_region;
   maximum_time_between_adjacent: OPTIONAL Time_data_element;
   minimum_time_between_adjacent: OPTIONAL Time_data_element;
   infill_method          : OPTIONAL text;
END_ENTITY;
```

1.9.1 region_description

a description of the region where a type of strategy applies.

1.9.2 maximum_time_between_adjacent

The maximum time gap allowed between hatching of adjacent islands or stripes.

Note: After this time the material will be too cold.

1.9.3 minimum_time_between_adjacent

The minimum time gap allowed between hatching of adjacent islands or stripes.

Note: Before this time the material will be too hot.

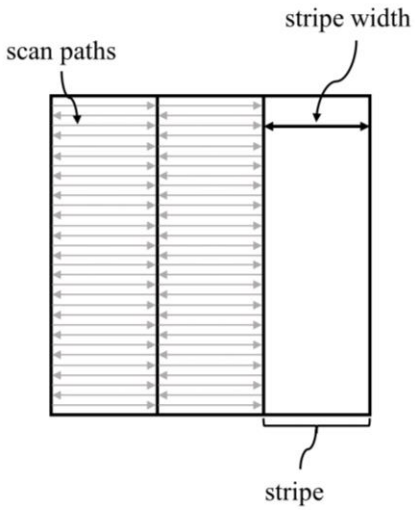
1.9.4 infill_method

a descrition of the pattern used for the infill.

Note: Normally the pattern is bidirectional, the scan_strategy allows other patterns to be described such as unidirectional or spiral.

1.10 Am_stripe_strategy

The Am_stripe_strategy application object divides each layer into stripes of a given width.




```
ENTITY Am_stripe_strategy
SUBTYPE OF (Am_hatch_strategy);
   stripe_width     : Length_data_element;
   contour_overlap  : Length_data_element;
   stripe_overlap   : Length_data_element;
END_ENTITY;
```

1.10.1 stripe_width

the width of each stripe.

1.10.2 contour_overlap

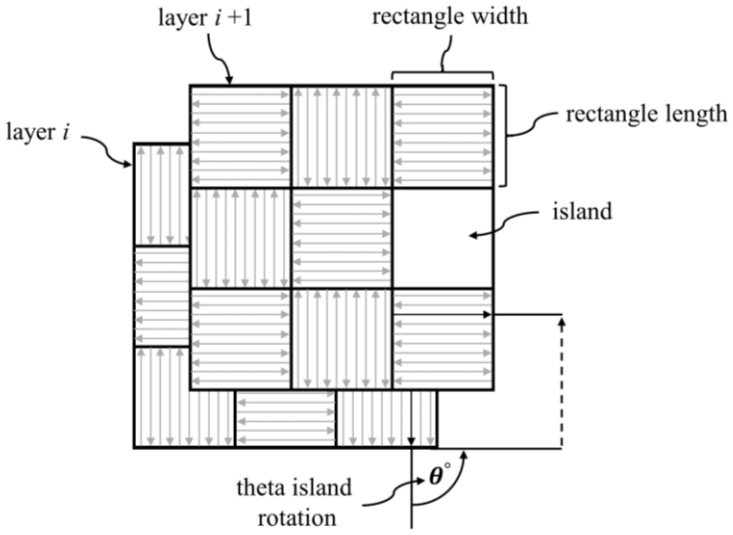
overlap of a stripe at an edge into the final contour to ensure seamless melting.

1.10.3 stripe_overlap

overlap between stripes to ensure seamless melting.

1.11 Am_chess_strategy

The Am_chess_strategy application object divides each layer into rectangular patches, also called islands. A length and width are specified for each island. The theta_island_rotation describes an optional rotation from the previous island.




```
ENTITY Am_chess_strategy
SUBTYPE OF (Am_hatch_strategy);
   rectangle_length : Length_data_element;
   rectangle_width  : Length_data_element;
   theta_island_rotation: OPTIONAL Angle_data_element;
   contour_overlap  : Length_data_element;
   island_overlap   : Length_data_element;
END_ENTITY;
```

1.11.1 rectangle_length

the length of an island.

1.11.2 rectangle_width

the width of an island.

1.11.3 theta_island_rotation

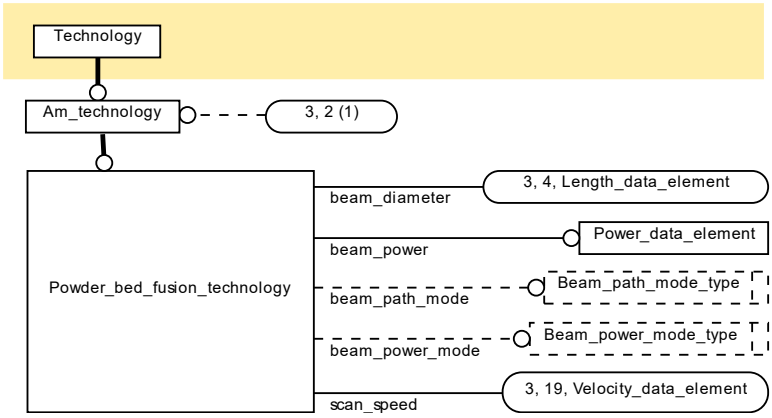
a rotation angle (θ) to change the orientation of the hatch paths in each new island.

1.11.4 contour_overlap

overlap of an island at an edge into the final contour to ensure seamless melting.

1.11.5 island_overlap

Overlap between islands to ensure seamless melting.



Powder Bed Fusion Technology

1.12 Am_technology

The Am_technology application object provides categorization of AM processes based on the characteristics that determine each additive process as defined in ISO/ASTM 52900 [2]. The AM technology entity is a subtype of the Technology entity that is defined in ISO 14649-10.

```
ENTITY Am_technology
SUBTYPE OF (technology);
END_ENTITY
```

1.13 Powder_bed_fusion_technology

Powder bed fusion application object is a category of AM technologies that uses a thermal energy beam to selectively fuse powder material into geometric patterns. The powder_bed_fusion defines the power, spot diameter, and scan speed of the thermal energy beam.

```
ENTITY Powder_bed_fusion_technology
SUBTYPE OF (Am_technology);
   beam_diameter    : Length_data_element;
   beam_power       : Power_data_element;
   beam_path_mode   : OPTIONAL Beam_path_mode_type;
   beam_power_mode  : OPTIONAL Beam_power_mode_type;
   scan_speed       : Velocity_data_element;
END_ENTITY;

TYPE Beam_path_mode_type = ENUMERATION OF (exact_stop, constant_build_speed,
continuous);
END_TYPE;

TYPE Beam_power_mode_type = ENUMERATION OF (constant_power, constant_power_density);
END_TYPE;
```

ENTITY powder_bed_fusion_technology

1.13.1 beam_diameter

the spot diameter of the beam.

Note: for a Gaussian beam profile, assume beam_diameter = d4 sigma, as defined by ISO 11146

1.13.2 beam_power

the energy output of the beam.

1.13.3 beam_path_mode

the type of transition between scan paths.

- exact_stop: stop the beam movement at the exact end of each move;
- constant_build_speed: keep the motion at a constant speed while the beam is switched on;
- continuous: matches the final speed with the starting speed of the following move.

1.13.4 beam_power_mode

the type of power management.

- constant_power: keeps the beam power constant during each move;
- constant_power_density: hold the power to speed ratio at a predefined constant during each move.

The formula for deriving the constant power density is given in equation (1) as follows,

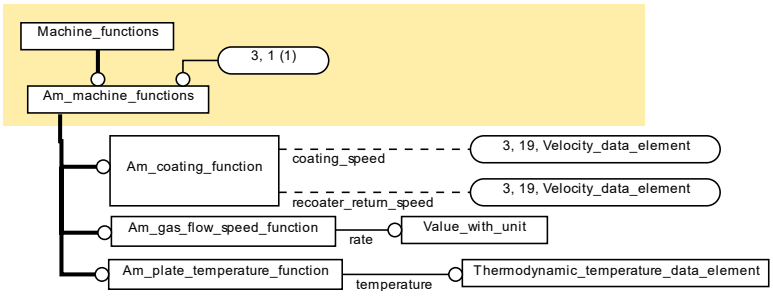
$$L = \left(\frac{V}{V_0}\right) \cdot C \cdot L_0 + (1 - C) \cdot L_0 \quad , \tag{1}$$

where V is the instantaneous speed in millimeters per second (mm/s), V_0 is the nominal speed in mm/s, C is a unitless weighting factor between 0 and 1, L_0 is the nominal laser power in Watts, and L is the applied laser power in Watts.

Note: The constant power density is controlled on the machine so the value of (C) does not need to be programmed.

1.13.5 scan_speed

the rate at which the beam moves over the scan path.



Powder Bed Fusion Machine Functions

1.14 Am_machine_functions

The Am_machine functions application object provides categorization of AM processes based on the characteristics that determine each additive process as defined in ISO/ASTM 52900 [2]. The AM machine functions entity is a subtype of the Machine functions entity that is defined in ISO 14649-10.

```
ENTITY Am_machine_functions
SUBTYPE OF (machine_functions);
END_ENTITY;
```

1.15 Am_coating_function

The Am_coating function application object defines a coating operation that adds a new layer of material onto the part.

```
ENTITY Am_coating_function
SUBTYPE OF (Am_machine_functions);
   coating_speed:          OPTIONAL Velocity_data_element;
   recoater_return_speed: OPTIONAL Velocity_data_element;
END_ENTITY;
```

1.15.1 coating_speed

the required speed for coating

1.15.2 recoater_return_speed

the required speed for returning the coater to the start position

NOTE: If the coating time differs from an assumed time, then there may be more or less cooling between layers.

1.16 Am_plate_temperature_function

The Am_plate_temperature function application object defines a required temperature for the build plate.

```
ENTITY Am_plate_temperature_function
SUBTYPE OF (Am_machine_functions);
   temperature      : Thermodynamic_temperature_data_element;
END_ENTITY;
```

1.16.1 temperature

the required temperature for the build plate.

1.17 Am_gas_flow_function

The Am_gas_flow function application object defines a rate for the gas flow.

```
ENTITY Am_gas_flow_speed_function
SUBTYPE OF (Am_machine_functions);
   rate             : Value_with_unit;
END_ENTITY;
```

1.17.1 rate

the required rate for the gas flow.

2 Powder Bed Fusion Mapping Specification

2.1 AM_PBF_OPERATION

```
AIM element: additive_type_operation
Source:      10303-238
Reference path:
additive_type_operation <=
```

```
machining_operation <=
action_method
{ ( action_method.description = 'pbf oned contour' )
 ( action_method.description = 'pbf oned infill' )
 ( action_method.description = 'pbf twod' )
 ( action_method.description = 'pbf threed' ) }
```

2.2 AM_ONED_PBF_OPERATION

```
AIM element: additive_type_operation
Source:      10303-238
Reference path:
additive_type_operation <=
machining_operation <=
action_method
{ ( action_method.description = 'pbf oned contour' )
 ( action_method.description = 'pbf oned infill' ) }
```

2.2.1 am_oned_pbf_operation to approach_retract_strategy (as approach)

```
AIM element: PATH
Reference path:
additive_type_operation <=
machining_operation <=
action_method <-
action_method_relationship.relating_method
action_method_relationship
{ action_method_relationship =>
machining_strategy_relationship }
{ action_method_relationship.name = 'approach' }
action_method_relationship.related_method ->
action_method =>
machining_strategy =>
machining_approach_retract_strategy
```

2.2.2 am_oned_pbf_operation to approach_retract_strategy (as retract)

```
AIM element: PATH
Reference path:
additive_type_operation <=
machining_operation <=
action_method <-
action_method_relationship.relating_method
action_method_relationship
{ action_method_relationship =>
machining_strategy_relationship }
{ action_method_relationship.name = 'retract' }
action_method_relationship.related_method ->
action_method =>
machining_strategy =>
machining_approach_retract_strategy
```

2.2.3 am_oned_pbf_operation to am_twod_pbf_operation (as its_twod_operation)

```
AIM element: PATH
Reference path:
additive_type_operation <=
machining_operation <=
action_method <-
action_method_relationship.relating_method
action_method_relationship
{ action_method_relationship =>
machining_operation_relationship }
{ action_method_relationship.name = 'twod' }
action_method_relationship.related_method ->
action_method =>
machining_operation =>
additive_type_operation
```

2.3 AM_ONED_PBF_CONTOUR_OPERATION

```
AIM element: additive_type_operation
Source:      10303-238
Reference path:
additive_type_operation <=
machining_operation <=
action_method
{ action_method.description = 'pbf oned contour' }
```

2.4 AM_ONED_PBF_INFILL_OPERATION

```
AIM element: additive_type_operation
Source:      10303-238
Reference path:
additive_type_operation <=
machining_operation <=
action_method
{ action_method.description = 'pbf oned infill' }
```

2.5 AM_TWOD_PBF_OPERATION

```
AIM element: additive_type_operation
Source:      10303-238
Reference path:
additive_type_operation <=
machining_operation <=
action_method
{ action_method.description = 'pbf twod' }
```

2.5.1 basis_surface

```
AIM element: elementary_surface
Source:      10303-42
Reference path:
additive_type_operation <=
machining_operation <=
action_method
characterized_action_definition = action_method
characterized_action_definition <-
action_property.definition
{ action_property.name = 'basis surface' }
action_property <-
action_property_representation.property
action_property_representation
action_property_representation.representation ->
representation
representation.items[i] ->
representation_item =>
compound_representation_item
compound_representation_item.item_element ->
compound_item_definition
compound_item_definition = list_representation_item
list_representation_item[i] ->
representation_item =>
geometric_representation_item =>
surface =>
elementary_surface
```

2.5.2 same_sense

#1: if value is true

#2: if value is false (mapping may be omitted if value is false)

```
AIM element: descriptive_representation_item.description
Source:      10303-45
Reference path:
additive_type_operation <=
machining_operation <=
action_method
characterized_action_definition = action_method
characterized_action_definition <-
action_property.definition
{ action_property.name = 'same sense' }
action_property <-
action_property_representation.property
action_property_representation
action_property_representation.representation ->
representation
representation.items[i] ->
representation_item =>
descriptive_representation_item
```

```
descriptive_representation_item.description
{ #1: (descriptive_representation_item.description = 'same sense' )
#2: (descriptive_representation_item. description = 'not same sense' ) }
```

2.5.3 hatch_space

```
AIM element: length_measure_with_unit
Source:      10303-41
Reference path:
additive_type_operation <=
machining_operation <=
action_method
characterized_action_definition = action_method
characterized_action_definition <-
action_property.definition
{ action_property.name = 'hatch space' }
action_property <-
action_property_representation.property
action_property_representation
action_property_representation.representation ->
representation
representation.items[i] ->
representation_item =>
measure_representation_item <=
measure_with_unit =>
length_measure_with_unit
```

2.5.4 am_twod_pbf_operation to am_threed_pbf_operation (as its_threed_operation)

```
AIM element: PATH
Reference path:
additive_type_operation <=
machining_operation <=
action_method <-
action_method_relationship.relating_method
action_method_relationship
{ action_method_relationship =>
machining_operation_relationship }
{ action_method_relationship.name = 'threed' }
action_method_relationship.related_method ->
action_method =>
machining_operation =>
additive_type_operation
```

2.5.5 am_twod_pbf_operation to am_contour_strategy (as its_contour_strategy)

```
AIM element: PATH
Reference path:
additive_type_operation <=
machining_operation <=
action_method <-
action_method_relationship.relating_method
```

```
action_method_relationship
{ action_method_relationship =>
machining_strategy_relationship }
{ action_method_relationship.name = 'contour' }
action_method_relationship.related_method ->
action_method =>
machining_strategy =>
additive_type_strategy
```

2.5.6 am_twod_pbf_operation to am_hatch_strategy (as its_hatch_strategy)

```
AIM element: PATH
Reference path:
additive_type_operation <=
machining_operation <=
action_method <-
action_method_relationship.relating_method
action_method_relationship
{ action_method_relationship =>
machining_strategy_relationship }
{ action_method_relationship.name = 'hatch' }
action_method_relationship.related_method ->
action_method =>
machining_strategy =>
additive_type_strategy
```

2.6 AM_THREED_PBF_OPERATION

```
AIM element: additive_type_operation
Source:      10303-238
Reference path:
additive_type_operation <=
machining_operation <=
action_method
{ action_method.description = 'pbf threed' }
```

2.6.1 theta_interlayer_rotation

```
AIM element: plane_angle_measure_with_unit
Source:      10303-41
Reference path:
additive_type_operation <=
machining_operation <=
action_method
characterized_action_definition = action_method
characterized_action_definition <-
action_property.definition
{ action_property.name = 'theta interlayer rotation' }
action_property <-
action_property_representation.property
action_property_representation
```

```
action_property_representation.representation ->
representation
representation.items[i] ->
representation_item =>
measure_representation_item <=
measure_with_unit =>
plane_angle_measure_with_unit
```

2.6.2 theta_initial_layer_rotation

```
AIM element: plane_angle_measure_with_unit
Source:      10303-41
Reference path:
additive_type_operation <=
machining_operation <=
action_method
characterized_action_definition = action_method
characterized_action_definition <-
action_property.definition
{ action_property.name = 'theta initial layer rotation' }
action_property <-
action_property_representation.property
action_property_representation
action_property_representation.representation ->
representation
representation.items[i] ->
representation_item =>
measure_representation_item <=
measure_with_unit =>
plane_angle_measure_with_unit
```

2.6.3 restriction_angle

```
AIM element: plane_angle_measure_with_unit
Source:      10303-41
Reference path:
additive_type_operation <=
machining_operation <=
action_method
characterized_action_definition = action_method
characterized_action_definition <-
action_property.definition
{ action_property.name = 'restriction angle' }
action_property <-
action_property_representation.property
action_property_representation
action_property_representation.representation ->
representation
representation.items[i] ->
representation_item =>
measure_representation_item <=
measure_with_unit =>
plane_angle_measure_with_unit
```

2.6.4 layer_thickness

```
AIM element: length_measure_with_unit
Source:      10303-41
Reference path:
additive_type_operation <=
machining_operation <=
action_method
characterized_action_definition = action_method
characterized_action_definition <-
action_property.definition
{ action_property.name = 'layer thickness' }
action_property <-
action_property_representation.property
action_property_representation
action_property_representation.representation ->
representation
representation.items[i] ->
representation_item =>
measure_representation_item <=
measure_with_unit =>
length_measure_with_unit
```

2.6.5 am_threed_pbf_operation to am_hatch_strategy (as its_hatch_strategy)

```
AIM element: PATH
Reference path:
additive_type_operation <=
machining_operation <=
action_method <-
action_method_relationship.relating_method
action_method_relationship
{ action_method_relationship =>
machining_strategy_relationship }
{ action_method_relationship.name = 'hatch' }
action_method_relationship.related_method ->
action_method =>
machining_strategy =>
additive_type_strategy
```

2.6.6 am_threed_pbf_operation to am_contour_strategy (as its_contour_strategy)

```
AIM element: PATH
Reference path:
additive_type_operation <=
machining_operation <=
action_method <-
action_method_relationship.relating_method
action_method_relationship
{ action_method_relationship =>
machining_strategy_relationship }
{ action_method_relationship.name = 'contour' }
```

```
action_method_relationship.related_method ->
action_method =>
machining_strategy =>
additive_type_strategy
```

2.7 AM_CONTOUR_STRATEGY

```
AIM element: additive_type_strategy
Source:      10303-238
Reference path:
additive_type_strategy <=
machining_strategy <=
action_method
{ action_method.description = 'pbf contour' }
```

2.7.1 am_contour_strategy to am_region (as region_description)

```
AIM element: PATH
Reference path:
additive_type_strategy <=
machining_strategy <=
action_method
characterized_action_definition = action_method
characterized_action_definition <-
action_property.definition
{ action_property.name = 'region' }
action_property <-
action_property_representation.property
action_property_representation
action_property_representation.representation ->
representation
```

2.7.2 pre_countour_count

```
AIM element: count_measure
Source:      10303-41
Reference path:
additive_type_strategy <=
machining_strategy <=
action_method
characterized_action_definition = action_method
characterized_action_definition <-
action_property.definition
{ action_property.name = 'pre contour count' }
action_property <-
action_property_representation.property
action_property_representation
action_property_representation.representation ->
representation
representation.items[i] ->
representation_item =>
```

```
measure_representation_item <=
measure_with_unit =>
measure_with_unit.value_component ->
measure_value
measure_value = count_measure
count_measure
```

2.7.3 pre_contour_offset

```
AIM element: length_measure_with_unit
Source:      10303-41
Reference path:
additive_type_strategy <=
machining_strategy <=
action_method
characterized_action_definition = action_method
characterized_action_definition <-
action_property.definition
{ action_property.name = 'pre contour offset' }
action_property <-
action_property_representation.property
action_property_representation
action_property_representation.representation ->
representation
representation.items[i] ->
representation_item =>
measure_representation_item <=
measure_with_unit =>
length_measure_with_unit
```

2.7.4 post_contour_count

```
AIM element: count_measure
Source:      10303-41
Reference path:
additive_type_strategy <=
machining_strategy <=
action_method
characterized_action_definition = action_method
characterized_action_definition <-
action_property.definition
{ action_property.name = 'post contour count' }
action_property <-
action_property_representation.property
action_property_representation
action_property_representation.representation ->
representation
representation.items[i] ->
representation_item =>
measure_representation_item <=
measure_with_unit =>
measure_with_unit.value_component ->
measure_value
```

```
measure_value = count_measure
count_measure
```

2.7.5 post_contour_offset

```
AIM element: length_measure_with_unit
Source:      10303-41
Reference path:
additive_type_strategy <=
machining_strategy <=
action_method
characterized_action_definition = action_method
characterized_action_definition <-
action_property.definition
{ action_property.name = 'post contour offset' }
action_property <-
action_property_representation.property
action_property_representation
action_property_representation.representation ->
representation
representation.items[i] ->
representation_item =>
measure_representation_item <=
measure_with_unit =>
length_measure_with_unit
```

2.7.6 compensate

#1: if value is true

#2: if value is false (mapping may be omitted if value is false)

```
AIM element: descriptive_representation_item.description
Source:      10303-45
Reference path:
additive_type_strategy <=
machining_strategy <=
action_method
characterized_action_definition = action_method
characterized_action_definition <-
action_property.definition
{ action_property.name = 'compensate' }
action_property <-
action_property_representation.property
action_property_representation
action_property_representation.representation ->
representation
representation.items[i] ->
representation_item =>
descriptive_representation_item
descriptive_representation_item.description
{ #1: (descriptive_representation_item.description = 'compensate' )
```

```
#2: (descriptive_representation_item. description = 'not compensate' ) }
```

2.7.7 edge_overlap

```
AIM element: length_measure_with_unit
Source:      10303-41
Reference path:
additive_type_strategy <=
machining_strategy <=
action_method
characterized_action_definition = action_method
characterized_action_definition <-
action_property.definition
{ action_property.name = 'edge overlap' }
action_property <-
action_property_representation.property
action_property_representation
action_property_representation.representation ->
representation
representation.items[i] ->
representation_item =>
measure_representation_item <=
measure_with_unit =>
length_measure_with_unit
```

2.7.8 contour_method

```
AIM element: descriptive_representation_item.description
Source:      10303-45
Reference path:
additive_type_strategy <=
machining_strategy <=
action_method
characterized_action_definition = action_method
characterized_action_definition <-
action_property.definition
{ action_property.name = 'contour method' }
action_property <-
action_property_representation.property
action_property_representation
action_property_representation.representation ->
representation
representation.items[i] ->
representation_item =>
descriptive_representation_item
descriptive_representation_item.description
```

2.8 AM_REGION

```
AIM element: representation
Source:      10303-43
```

```
Reference path:
representation
{representation.name = 'pbf region' }
```

2.8.1 region_type

```
AIM element: descriptive_representation_item.description
Source:      10303-45
Reference path:
representation
representation.items[i] ->
{ representation_item.name = 'region type' }
representation_item =>
descriptive_representation_item
descriptive_representation_item.description
{ (descriptive_representation_item.description = 'core' )
(descriptive_representation_item. description = 'upskin' )
(descriptive_representation_item. description = 'downskin' )
(descriptive_representation_item. description = 'future hole' )
(descriptive_representation_item. description = 'support' )
(descriptive_representation_item. description = 'small' )
(descriptive_representation_item. description = 'large' ) }
```

2.8.2 layer_count

```
AIM element: count_measure
Source:      10303-41
Reference path:
representation
representation.items[i] ->
{ representation_item.name = 'layer count' }
representation_item =>
measure_representation_item <=
measure_with_unit =>
measure_with_unit.value_component ->
measure_value
measure_value = count_measure
count_measure
```

2.8.3 high_angle

```
AIM element: plane_angle_measure_with_unit
Source:      10303-41
Reference path:
representation
representation.items[i] ->
{ representation_item.name = 'high angle' }
representation_item =>
measure_representation_item <=
measure_with_unit =>
plane_angle_measure_with_unit
```

2.8.4 low_angle

```
AIM element: plane_angle_measure_with_unit
Source:      10303-41
Reference path:
representation
representation.items[i] ->
{ representation_item.name = 'low angle' }
representation_item =>
measure_representation_item <=
measure_with_unit =>
plane_angle_measure_with_unit
```

2.8.5 small_area

```
AIM element: measure_with_unit
Source:    10303-41
Reference path:
representation
representation.items[i] ->
{ representation_item.name = 'small area' }
representation_item =>
measure_representation_item <=
measure_with_unit
{ measure_with_unit.value_component ->
measure_value
measure_value = numeric_measure
numeric_measure }
```

2.8.6 large_area

```
AIM element: measure_with_unit
Source:    10303-41
Reference path:
representation
representation.items[i] ->
{ representation_item.name = 'large area' }
representation_item =>
measure_representation_item <=
measure_with_unit
{ measure_with_unit.value_component ->
measure_value
measure_value = numeric_measure
numeric_measure }
```

2.9 AM_HATCH_STRATEGY

```
AIM element: additive_type_strategy
Source:      10303-238
Reference path:
additive_type_strategy <=
```

```
machining_strategy <=
action_method
{ ( action_method.description = 'pbf hatch chess' )
( action_method.description = 'pbf hatch stripe' ) }
```

2.9.1 am_hatch_strategy to am_region (as region_description)

```
AIM element: PATH
Reference path:
additive_type_strategy <=
machining_strategy <=
action_method
characterized_action_definition = action_method
characterized_action_definition <-
action_property.definition
{ action_property.name = 'region' }
action_property <-
action_property_representation.property
action_property_representation
action_property_representation.representation ->
representation
```

2.9.2 maximum_time_between_adjacent

```
AIM element: time_measure_with_unit
Source:      10303-41
Reference path:
additive_type_strategy <=
machining_strategy <=
action_method
characterized_action_definition = action_method
characterized_action_definition <-
action_property.definition
{ action_property.name = 'maximum time between adjacent' }
action_property <-
action_property_representation.property
action_property_representation
action_property_representation.representation ->
representation
representation.items[i] ->
representation_item =>
measure_representation_item <=
measure_with_unit =>
time_measure_with_unit
```

2.9.3 minimum_time_between_adjacent

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

```
Reference path:
additive_type_strategy <=
machining_strategy <=
action_method
characterized_action_definition = action_method
characterized_action_definition <-
action_property.definition
{ action_property.name = 'minimum time between adjacent' }
action_property <-
action_property_representation.property
action_property_representation
action_property_representation.representation ->
representation
representation.items[i] ->
representation_item =>
measure_representation_item <=
measure_with_unit =>
time_measure_with_unit
```

2.9.4 infill_method

```
AIM element: descriptive_representation_item.description
Source:      10303-45
Reference path:
additive_type_strategy <=
machining_strategy <=
action_method
characterized_action_definition = action_method
characterized_action_definition <-
action_property.definition
{ action_property.name = 'infill method' }
action_property <-
action_property_representation.property
action_property_representation
action_property_representation.representation ->
representation
representation.items[i] ->
representation_item =>
descriptive_representation_item
descriptive_representation_item.description
```

2.10 AM_STRIPE_STRATEGY

```
AIM element: additive_type_strategy
Source:      10303-238
Reference path:
additive_type_strategy <=
machining_strategy <=
action_method
{ action_method.description = 'pbf hatch stripe' }
```

2.10.1 stripe_width

```
AIM element: length_measure_with_unit
Source:      10303-41
Reference path:
additive_type_strategy <=
machining_strategy <=
action_method
characterized_action_definition = action_method
characterized_action_definition <-
action_property.definition
{ action_property.name = 'stripe width' }
action_property <-
action_property_representation.property
action_property_representation
action_property_representation.representation ->
representation
representation.items[i] ->
representation_item =>
measure_representation_item <=
measure_with_unit =>
length_measure_with_unit
```

2.10.2 contour_overlap

```
AIM element: length_measure_with_unit
Source:      10303-41
Reference path:
additive_type_strategy <=
machining_strategy <=
action_method
characterized_action_definition = action_method
characterized_action_definition <-
action_property.definition
{ action_property.name = 'contour overlap' }
action_property <-
action_property_representation.property
action_property_representation
action_property_representation.representation ->
representation
representation.items[i] ->
representation_item =>
measure_representation_item <=
measure_with_unit =>
length_measure_with_unit
```

2.10.3 stripe_overlap

```
AIM element: length_measure_with_unit
Source:      10303-41
Reference path:
additive_type_strategy <=
```

```
machining_strategy <=
action_method
characterized_action_definition = action_method
characterized_action_definition <-
action_property.definition
{ action_property.name = 'stripe overlap' }
action_property <-
action_property_representation.property
action_property_representation
action_property_representation.representation ->
representation
representation.items[i] ->
representation_item =>
measure_representation_item <=
measure_with_unit =>
length_measure_with_unit
```

2.11 AM_CHESS_STRATEGY

```
AIM element: additive_type_strategy
Source:      10303-238
Reference path:
additive_type_strategy <=
machining_strategy <=
action_method
{ action_method.description = 'pbf hatch chess' }
```

2.11.1 rectangle_length

```
AIM element: length_measure_with_unit
Source:      10303-41
Reference path:
additive_type_strategy <=
machining_strategy <=
action_method
characterized_action_definition = action_method
characterized_action_definition <-
action_property.definition
{ action_property.name = 'rectangle length' }
action_property <-
action_property_representation.property
action_property_representation
action_property_representation.representation ->
representation
representation.items[i] ->
representation_item =>
measure_representation_item <=
measure_with_unit =>
length_measure_with_unit
```

2.11.2 rectangle_width

```
AIM element: length_measure_with_unit
Source:      10303-41
Reference path:
additive_type_strategy <=
machining_strategy <=
action_method
characterized_action_definition = action_method
characterized_action_definition <-
action_property.definition
{ action_property.name = 'rectangle width' }
action_property <-
action_property_representation.property
action_property_representation
action_property_representation.representation ->
representation
representation.items[i] ->
representation_item =>
measure_representation_item <=
measure_with_unit =>
length_measure_with_unit
```

2.11.3 theta_island_rotation

```
AIM element: plane_angle_measure_with_unit
Source:      10303-41
Reference path:
additive_type_strategy <=
machining_strategy <=
action_method
characterized_action_definition = action_method
characterized_action_definition <-
action_property.definition
{ action_property.name = 'theta island rotation' }
action_property <-
action_property_representation.property
action_property_representation
action_property_representation.representation ->
representation
representation.items[i] ->
representation_item =>
measure_representation_item <=
measure_with_unit =>
plane_angle_measure_with_unit
```

2.11.4 contour_overlap

```
AIM element: length_measure_with_unit
Source:      10303-41
Reference path:
additive_type_strategy <=
```

```
machining_strategy <=
action_method
characterized_action_definition = action_method
characterized_action_definition <-
action_property.definition
{ action_property.name = 'contour overlap' }
action_property <-
action_property_representation.property
action_property_representation
action_property_representation.representation ->
representation
representation.items[i] ->
representation_item =>
measure_representation_item <=
measure_with_unit =>
length_measure_with_unit
```

2.11.5 island_overlap

```
AIM element: length_measure_with_unit
Source:      10303-41
Reference path:
additive_type_strategy <=
machining_strategy <=
action_method
characterized_action_definition = action_method
characterized_action_definition <-
action_property.definition
{ action_property.name = 'island overlap' }
action_property <-
action_property_representation.property
action_property_representation
action_property_representation.representation ->
representation
representation.items[i] ->
representation_item =>
measure_representation_item <=
measure_with_unit =>
length_measure_with_unit
```

2.12 POWDER_BED_FUSION_TECHNOLOGY

```
AIM element: machining_technology
Source:      10303-238
Reference path:
machining_technology <=
action_method
{ action_method.description = 'additive pbf' }
```

2.12.1 beam_diameter

```
AIM element: length_measure_with_unit
Source:      10303-41
Reference path:
additive_type_strategy <=
machining_strategy <=
action_method
characterized_action_definition = action_method
characterized_action_definition <-
action_property.definition
{ action_property.name = 'beam diameter' }
action_property <-
action_property_representation.property
action_property_representation
action_property_representation.representation ->
representation
representation.items[i] ->
representation_item =>
measure_representation_item <=
measure_with_unit =>
length_measure_with_unit
```

2.12.2 beam_power

```
AIM element: measure_with_unit
Source:      10303-41
Reference path:
machining_technology <=
action_method
characterized_action_definition = action_method
characterized_action_definition <-
action_property.definition
{ action_property.name = 'beam power' }
action_property <-
action_property_representation.property
action_property_representation
action_property_representation.representation ->
representation
representation.items[i] ->
representation_item =>
measure_representation_item <=
measure_with_unit
{ measure_with_unit.value_component ->
measure_value
measure_value = numeric_measure
numeric_measure }
```

2.12.3 beam_path_mode

```
AIM element: descriptive_representation_item.description
Source:      10303-45
```

```
Reference path:
machining_technology <=
action_method
characterized_action_definition = action_method
characterized_action_definition <-
action_property.definition
{ action_property.name = 'beam path mode' }
action_property <-
action_property_representation.property
action_property_representation
action_property_representation.representation ->
representation
representation.items[i] ->
representation_item =>
descriptive_representation_item
descriptive_representation_item.description
{ (descriptive_representation_item.description = ' exact stop' )
(descriptive_representation_item. description = 'constant build speed' )
(descriptive_representation_item. description = 'continuous' ) }
```

2.12.4 beam_power_mode

```
AIM element: descriptive_representation_item.description
Source:      10303-45
Reference path:
machining_technology <=
action_method
characterized_action_definition = action_method
characterized_action_definition <-
action_property.definition
{ action_property.name = 'beam power mode' }
action_property <-
action_property_representation.property
action_property_representation
action_property_representation.representation ->
representation
representation.items[i] ->
representation_item =>
descriptive_representation_item
descriptive_representation_item.description
{ (descriptive_representation_item.description = 'constant power' )
(descriptive_representation_item. description = 'constant power density' ) }
```

2.12.5 scan_speed

```
AIM element: measure_with_unit
Source:      10303-41
Reference path:
machining_technology <=
action_method
characterized_action_definition = action_method
characterized_action_definition <-
action_property.definition
```

```
{ action_property.name = 'scan speed' }
action_property <-
action_property_representation.property
action_property_representation
action_property_representation.representation ->
representation
representation.items[i] ->
representation_item =>
measure_representation_item <=
measure_with_unit
{ measure_with_unit.value_component ->
measure_value
measure_value = numeric_measure
numeric_measure }
```

2.13 AM_COATING_FUNCTION

```
AIM element: machining_functions
Source:      10303-238
Reference path:
machining_functions <=
action_method
{ action_method.description = 'coating' }
```

2.13.1 coating_speed

```
AIM element: measure_with_unit
Source:      10303-41
Reference path:
machining_functions <=
action_method
characterized_action_definition = action_method
characterized_action_definition <-
action_property.definition
{ action_property.name = 'coating speed' }
action_property <-
action_property_representation.property
action_property_representation
action_property_representation.representation ->
representation
representation.items[i] ->
representation_item =>
measure_representation_item <=
measure_with_unit
{ measure_with_unit.value_component ->
measure_value
measure_value = numeric_measure
numeric_measure }
```

2.13.2 recoater_return_speed

```
AIM element: measure_with_unit
Source:      10303-41
Reference path:
machining_functions <=
action_method
characterized_action_definition = action_method
characterized_action_definition <-
action_property.definition
{ action_property.name = 'recoater return speed' }
action_property <-
action_property_representation.property
action_property_representation
action_property_representation.representation ->
representation
representation.items[i] ->
representation_item =>
measure_representation_item <=
measure_with_unit
{ measure_with_unit.value_component ->
measure_value
measure_value = numeric_measure
numeric_measure }
```

2.14 AM_PLATE_TEMPERATURE_FUNCTION

```
AIM element: machining_functions
Source:      10303-238
Reference path:
machining_functions <=
action_method
{ action_method.description = 'plate temperature' }
```

2.14.1 temperature

```
AIM element: measure_with_unit
Source:      10303-41
Reference path:
machining_functions <=
action_method
characterized_action_definition = action_method
characterized_action_definition <-
action_property.definition
{ action_property.name = 'temperature' }
action_property <-
action_property_representation.property
action_property_representation
action_property_representation.representation ->
representation
representation.items[i] ->
representation_item =>
```

```
measure_representation_item <=
measure_with_unit
{ measure_with_unit.value_component ->
measure_value
measure_value = thermodynamic_temperature_measure
thermodynamic_temperature_measure }
```

2.15 AM_GAS_FLOW_SPEED_FUNCTION

```
AIM element: machining_functions
Source:      10303-238
Reference path:
machining_functions <=
action_method
{ action_method.description = 'gas flow' }
```

2.15.1 rate

```
AIM element: measure_with_unit
Source:      10303-41
Reference path:
machining_functions <=
action_method
characterized_action_definition = action_method
characterized_action_definition <-
action_property.definition
{ action_property.name = 'flow rate' }
action_property <-
action_property_representation.property
action_property_representation
action_property_representation.representation ->
representation
representation.items[i] ->
representation_item =>
measure_representation_item <=
measure_with_unit
{ measure_with_unit.value_component ->
measure_value
measure_value = numeric_measure
numeric_measure }
```

3 AIM EXPRESS Additions

3.1 additive_type_strategy

An **additive_type_strategy** is a type of **machining_strategy** that represents the details of an additive manufacturing strategy of a machining process.

3.1.1 EXPRESS specification:

```
*)
ENTITY additive_type_strategy
  SUBTYPE OF (machining_strategy);
END_ENTITY;
(*
```