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20240331_ap238e4_composites

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	2024-04-01	**INFO**

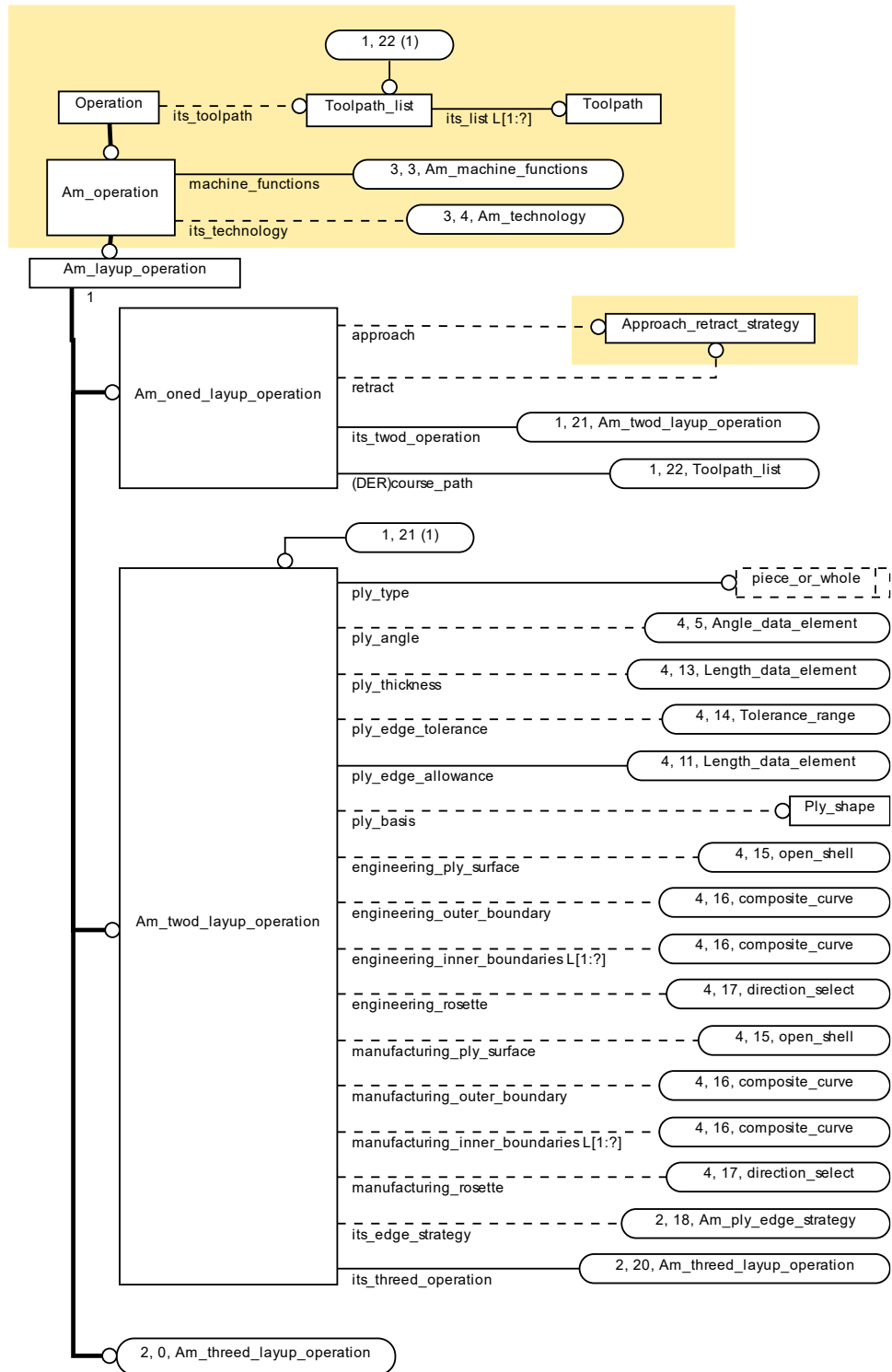**Replaces:** N 262 20240313_ap238e4_composites

Description

Composites layup model after editing in Renton

AP238 Extension for Composite Layup

This document describes the ARM/AIM mappings for an AP238 extension for the automation of processes that lay composite plys.

1 Application Objects

Composite Operations

1.1 AM_layup_operation

The AM_layup_operation application object defines the machine functions and technology to be used in a layup oeration. The Am_layup_operation application object inherits from the am_operation as defined in ISO 14649-17 [1],

```
ENTITY Am_layup_operation
ABSTRACT SUPERTYPE OF (ONEOF (am_oned_layup_operation, am_twod_layup_operation,
am_threed_layup_operation))
SUBTYPE OF (Am_operation);
    -- machine_functions:        am_machine_functions;
    -- its_technology:           am_technology;
END_ENTITY;
```

1.1.1 machine_functions

the machine functions required for this operation.

1.1.2 its_technology

the processing technology to be used for this operation.
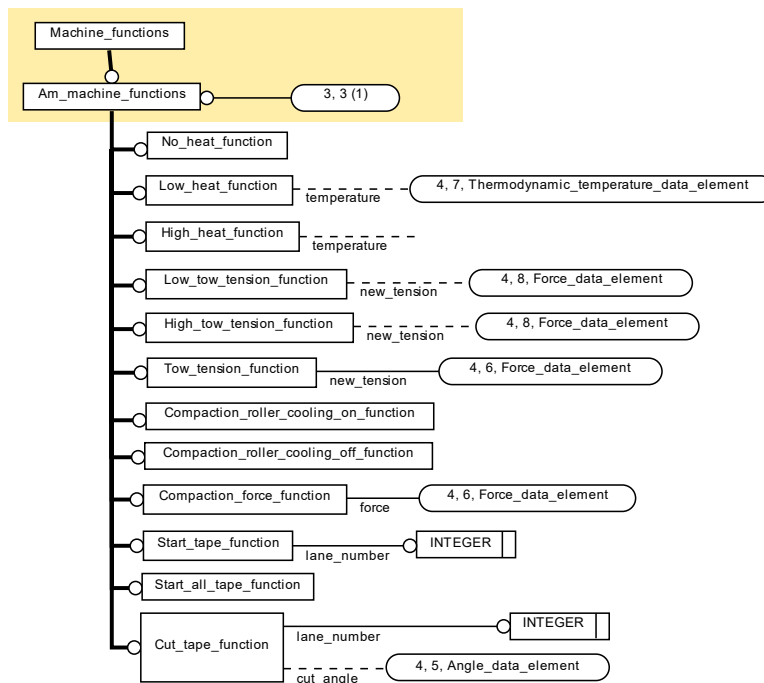
Machine Functions

1.2 Cut_tape_function

The cut tape application object is an AM machine function that cuts a tape during a layup.

```
ENTITY Cut_tape_function
SUBTYPE OF (Am_machine_functions);
  lane_number: INTEGER;
  cut_angle  : OPTIONAL Angle_data_element;
END_ENTITY;
```

NOTE: For example, in the middle of a course the first or last tape may need to be cut avoid overlaps.
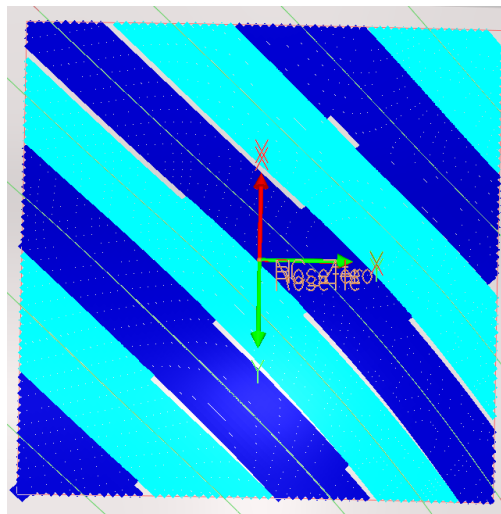
Cut tapes in courses

1.2.1 lane_number

The lane number of the tow that is to be cut.

NOTE: The lane number is an index into the maximum_number_of_lanes as defined in the threed_layup_operation.

1.2.2 cut_angle

The angle to cut the tape.

NOTE: In most situations a tape must be half inch or larger for a cut angle to be allowed.

1.3   Start_tape_function

The start tape application object is an AM machine function that starts tape laying in a lane.

```
ENTITY Start_tape_function
SUBTYPE OF (Am_machine_functions);
  lane_number: INTEGER;
END_ENTITY;
```

1.3.1   lane_number

The lane number of the tow that is to be started or restarted.

NOTE: The lane number is an index into the maximum_number_of_lanes as defined in the threed_layup_operation.

1.4   Start_all_tape_function

The start all tape application object is an AM machine function that starts tape laying in all the lanes of the course

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

NOTE: The number of lanes in a course is set in the oned_layup_operation and may not be the same as the maiximum number of tapes allowed in the tow.

1.5   Compaction_roller_cooling_on_function

The compaction_roller_cooling_on application object is an AM machine function that turns cooling on for the compaction roller.

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

1.6   Compaction_roller_cooling_off_function

The compaction_roller_cooling_on application object is an AM machine function that turns cooling off for the compaction roller.

```
ENTITY Compaction_roller_cooling_off_function
SUBTYPE OF (Am_machine_functions);
```

```
END_ENTITY;
```

1.7 Compaction_force_function

The compaction_force application object is an AM machine function that defines a force for the compaction roller.

```
ENTITY Compaction_force_function
SUBTYPE OF (Am_machine_functions);
  force       : Force_data_element;
END_ENTITY;
```

1.7.1 force

the force to be applied for compaction

1.8 High_heat_function

The high heat application object is an AM machine function that sets the tape heater to high.

```
ENTITY High_heat_function
SUBTYPE OF (Am_machine_functions);
  Temperature       : OPTIONAL Thermodynamic_temperature_data_element;
END_ENTITY;
```

1.8.1 temperature

the desired temperature for the heater.

1.9 Low_heat_function

The low heat application object is an AM machine function that sets the tape heater to low.

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

1.9.1 temperature

the desired temperature for the heater.

1.10 No_heat_function

The no_heat application object is an AM machine function that turns the heater off.

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

1.11 Tow_tension_function

The tow_tension application object is an AM machine function that sets the tension of the tape.

```
ENTITY Tow_tension_function
SUBTYPE OF (Am_machine_functions);
    new_tension     : Force_data_element;
END_ENTITY;
```

1.11.1 New_tension

the new tow tension.

1.12 High_tow_tension_function

The tow_tension application object is an AM machine function sets the tension of the tape to high with an optional value.

```
ENTITY High_tow_tension_function
SUBTYPE OF (Am_machine_functions);
    new_tension     : OPTIONAL Force_data_element;
END_ENTITY;
```

1.12.1 New_tension

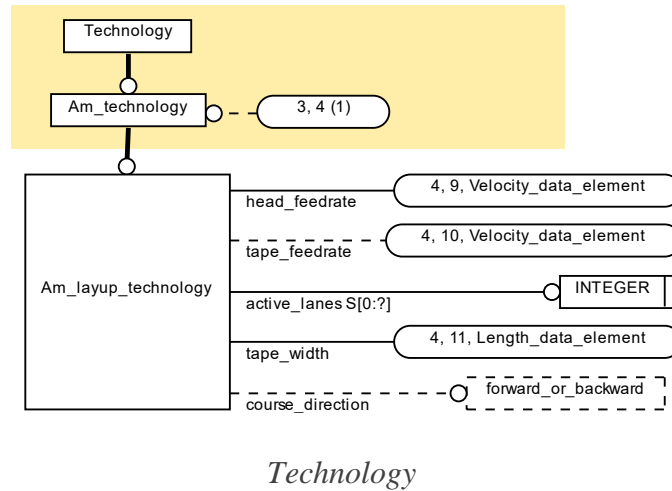the new tow tension.

1.13 Low_tow_tension_function

The low_tow_tension application object is an AM machine function that sets the tension of the tape to low with an optional value.

```
ENTITY Low_tow_tension_function
SUBTYPE OF (Am_machine_functions);
    new_tension: OPTIONAL Force_data_element;
```

```
END_ENTITY;
```

1.13.1 New_tension

the new tow tension.

Technology

1.14 Am_technology

The am_technology defines the technology process parameters for additive manufacturing operations.

```
ENTITY Am_technology
ABSTRACT SUPERTYPE
SUBTYPE OF (Technology);
END_ENTITY;
```

1.15 Am_layup_technology

The am_layup technology defines the speed of the layup and the width of the course.

```
ENTITY Am_layup_technology
SUBTYPE OF (Am_technology);
   head_feedrate    : Velocity_data_element;
   tape_feedrate    : OPTIONAL Velocity_data_element;
   active_lanes     : SET [0:?] OF INTEGER;
   tape_width       : Length_data_element;
   course_direction : OPTIONAL forward_or_backward;
END_ENTITY;

TYPE forward_or_backward = ENUMERATION OF (forward, backward); END_TYPE;
```

1.15.1 head_feedrate

the speed of the head as it moves on the course.

1.15.2 tape_feedrate

the speed of the tape as it is fed through the head.

NOTE: The tape feedrate needs to be higher than the head federate when the distance between the head and the surface is growing.

1.15.3 active_lanes

 the lane numbers of the active tows.

1.15.4 tape_width

the width of tape being laid in this course.

1.15.5 course_direction

the direction of the course classified as forward when in the direction of rosette, and backward when in direction opposite to the rosette.

NOTE: In most situations consecutive courses are laid in opposite directions.

1.16 AM_oned_layup_operation

The AM_oned_layup_operation application object defines a tow path for the tape.

```
ENTITY Am_oned_layup_operation
SUBTYPE OF (Am_layup_operation);
  approach   : OPTIONAL Approach_retract_strategy;
  retract    : OPTIONAL Approach_retract_strategy;
  its_twod_operation      : Am_twod_layup_operation;
DERIVE
  course_path : toolpath_list :=
      SELF\Operation.its_toolpath;
END_ENTITY;
```

1.16.1 approach

the strategy used to approach the course before tape laying begins.

1.16.2 retract

the strategy used to exit the course after tape laying ends.

1.16.3 its_twod_operation

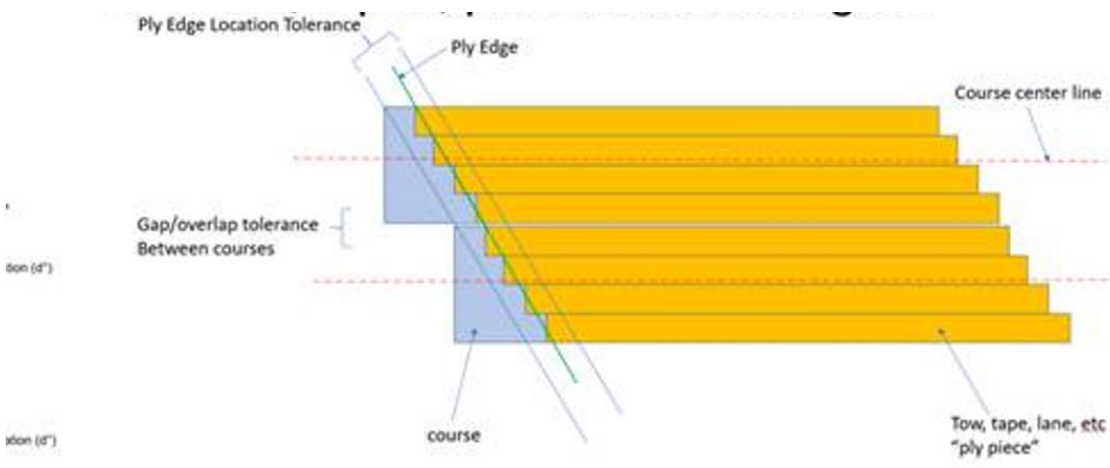the twod_layup_operation used to generate this oned_layup_operation.

1.16.4 course_path

the centerline of the path followed by the tape head.

NOTE: the course path is inherited from operation and shown here for clarity

1.17 Am_twod_layup_operation

The AM_twod_layup_operation application object defines information for generating AM_oned_layup operations.


```
-- operation is defined for the ply_piece in a workingstep
ENTITY Am_twod_layup_operation
SUBTYPE OF (Am_layup_operation);
  ply_type                   : piece_or_whole;
  ply_angle                  : OPTIONAL Angle_data_element;
  ply_thickness                    : OPTIONAL Length_data_element;
  ply_edge_tolerance               : OPTIONAL Tolerance_range;
  ply_edge_allowance               : Length_data_element;
  ply_basis                  : OPTIONAL Ply_shape;
  engineering_ply_surface : OPTIONAL open_shell;
  engineering_outer_boundary    : OPTIONAL composite_curve;
  engineering_inner_boundaries  : OPTIONAL LIST [1:?] OF composite_curve;
```

```
   engineering_rosette            : OPTIONAL Direction_select;
   manufacturing_ply_surface      : OPTIONAL open_shell;
   manufacturing_outer_boundary   : OPTIONAL composite_curve;
   manufacturing_inner_boundaries: OPTIONAL LIST [1:?] OF composite_curve;
   manufacturing_rosette          : OPTIONAL Direction_select;
   its_edge_strategy              : OPTIONAL Am_ply_edge_strategy;
   its_threed_operation           : Am_threed_layup_operation;
END_ENTITY;

TYPE piece_or_whole = ENUMERATION OF (ply_piece, ply_whole); END_TYPE;
```

1.17.1 ply_type

the operation is applied to a whole ply or a piece of a ply

- ply_piece: the operation is for a piece of a ply
- ply_whole: the operation is for a whole ply

NOTE: if the operation is for a ply_piece then the workpiece is a ply_piece, and if it is for a ply_whole then the workpiece is a ply.

1.17.2 ply_angle

the angle that the ply is to be laid relative to the basis of the composite assembly table.

NOTE: if not given then the angle is defined by the material_orientation of the ply product definition. Typical angle values for four consecutive plys are 0, 45, 90 and -45.

1.17.3 ply_thickness

the thickness of the layer.

NOTE: if not given the thickness is defined by the ply_thickness of the ply product definition.

1.17.4 ply_edge_tolerance

the tolerance allowed for the distance between the start of the tape and the edge.

1.17.5 ply_edge_allowance

an additional length of material to be laid before the engineering boundary if no manufacturing boundary is given.

1.17.6 ply_basis

the shape to be laid as defined for engineering or manufacturing.

NOTE: the basis may describe a shape for engineering, manufacturing or both.

1.17.7 engineering_ply_surface

the engineering surface to be laid laid during manufacturing.

NOTE: if not given the surface is the defining model of the ply shape.

1.17.8 engineering_outer_boundary

the engineering boundary on the surface to lay the tape within this boundary the ply must meet the requirements set by engineering.

NOTE: if not given the boundary is defined by the outer boundaries of the ply shape.

1.17.9 engineering_inner_boundaries

the engineering boundaries of any voids in the surface. No tape shall be laid within this boundary.

NOTE: if not given the boundary is defined by the inner boundaries of the ply shape.

1.17.10   engineering_rosette

the direction of the course as set by engineering. The x direction defines the direction of the course, the y direction defines the direction to offset the next course. The rosette may be defined by a point on a curve.

NOTE: if not given the rosette is as defined by the material_orientation of the ply product definition.

1.17.11   manufacturing_ply_surface

the manufacturing surface to be laid laid during manufacturing.

NOTE: if not given the surface is defined by the engineering_ply_surface.

1.17.12 manufacturing_outer_boundary

within the boundary the tape shall meet the requirements set by engineering but the material between the engineering_outer_boundary (EEOP) and the manufacturing_outer_boundary (MEOP) will be removed before assembly.

NOTE: if not given the boundary is the engineering boundary as modifed by the edge_allowance.

1.17.13 manufacturing_inner_boundaries

the manufacturing boundaries of any voids in the surface. If an empty boundary is given then tape may be laid across the entire void.

NOTE: tape may be laid between the design inner boundaries and the manufacturing inner boundaries. Excess tape will be machined away before assembly.

1.17.14 manufacturing_rosette

manufacturing specific advice for the direction of the course. The x direction defines the direction of the course, the y direction defines the direction to find the start point for the next course.
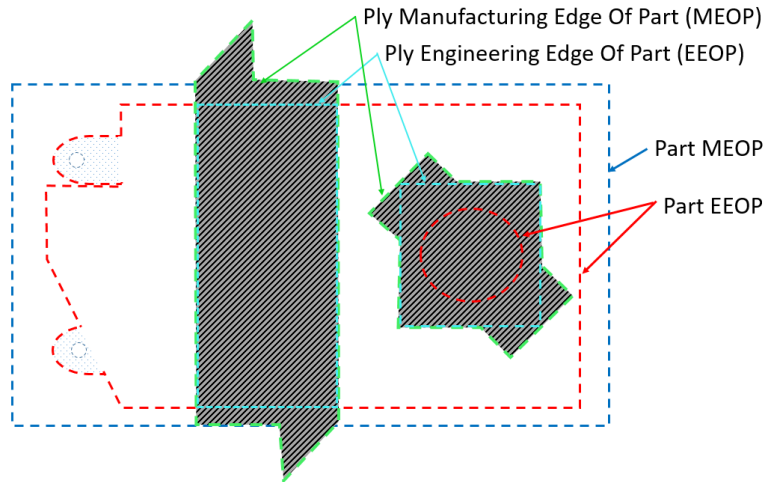
NOTE: if not given the rosette is as defined by the engineering rosette.

1.17.15 its_edge_strategy

the strategy to be used to control edges.

1.17.16 its_threed_operation

the threed_layup operation for this twod_layup operation.

Design (EEOP) and Manufacturing (MEOP) boundaries. If the ply_type is a ply_edge then the design and manufacturing boundaries are the Ply EEOP and Ply MEOP.

1.18 Am_ply_edge_strategy

The Am_ply_edge_strategy application object defines a strategy for managing manufacturing edges.

```
ENTITY Am_ply_edge_strategy;
  minimum_tape_length                 : Length_data_element;
  maximum_tow_overlap                 : Length_data_element;
  minimum_course_seperation           : Length_data_element;
  ply_course_minimum_zone             : OPTIONAL Ply_course_minimum_type;
  tow_alignment_boundary_conditon     : OPTIONAL Tow_edge_type;
END_ENTITY;

TYPE Ply_course_minimum_type = ENUMERATION OF (right_aligned, left_aligned,
centered); END_TYPE ;

TYPE Tow_edge_type = ENUMERATION OF (half, full, none); END_TYPE;
```

1.18.1 minimum_tape_length

the minimum length allowed for a tape. If a tape path is less then this length then it shall be extended using the selected ply course minimum type.

1.18.2 maximum_tow_overlap

the maximum overlap allowed between the last tape of the previous course and the first tape of the subsequent course.

1.18.3 minimum_course_seperation

the minimum gap allowed between the last tape of the previous course and the first tape of the subsequent course.

NOTE: If the requirements of the maximum overlap and the minimum_seperation cause too many gaps between tows then the tape width can be reduced.

1.18.4 ply_course_mimimum_zone

the preferred zone for material excess when there is a minimum length for laid material

NOTE: This material is laid beyond the manufacturing boundary to ensure the tape has sufficient length to bond.

Minimum length tow management for internal ply bounds of ±45°

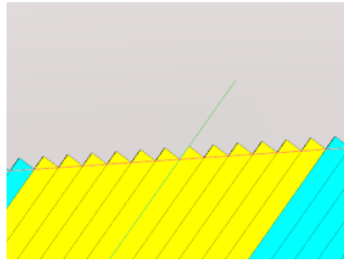Right Aligned   Left Aligned   Centered
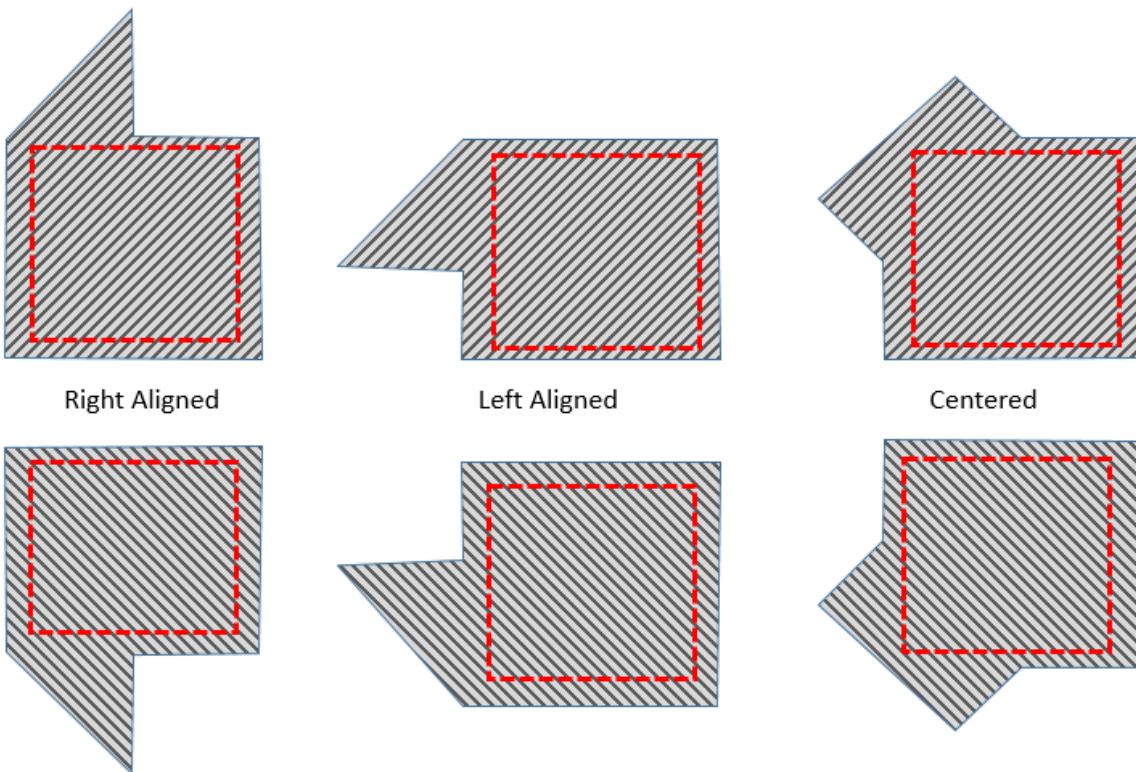
1.18.5 tow_alignment_boundary_condition

the edge to be met when cutting material on the manufacturing edge.

Tow Alignment to boundary condition (MEOP)
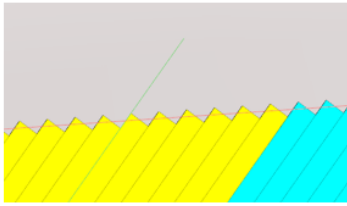
"Half"

"Full"
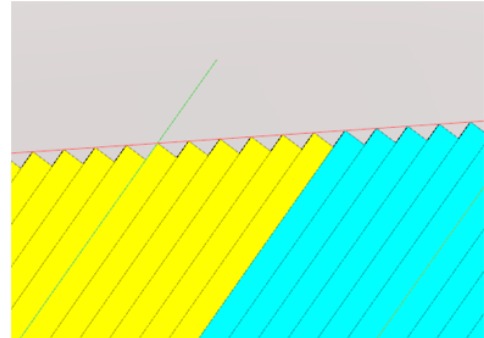
"None"
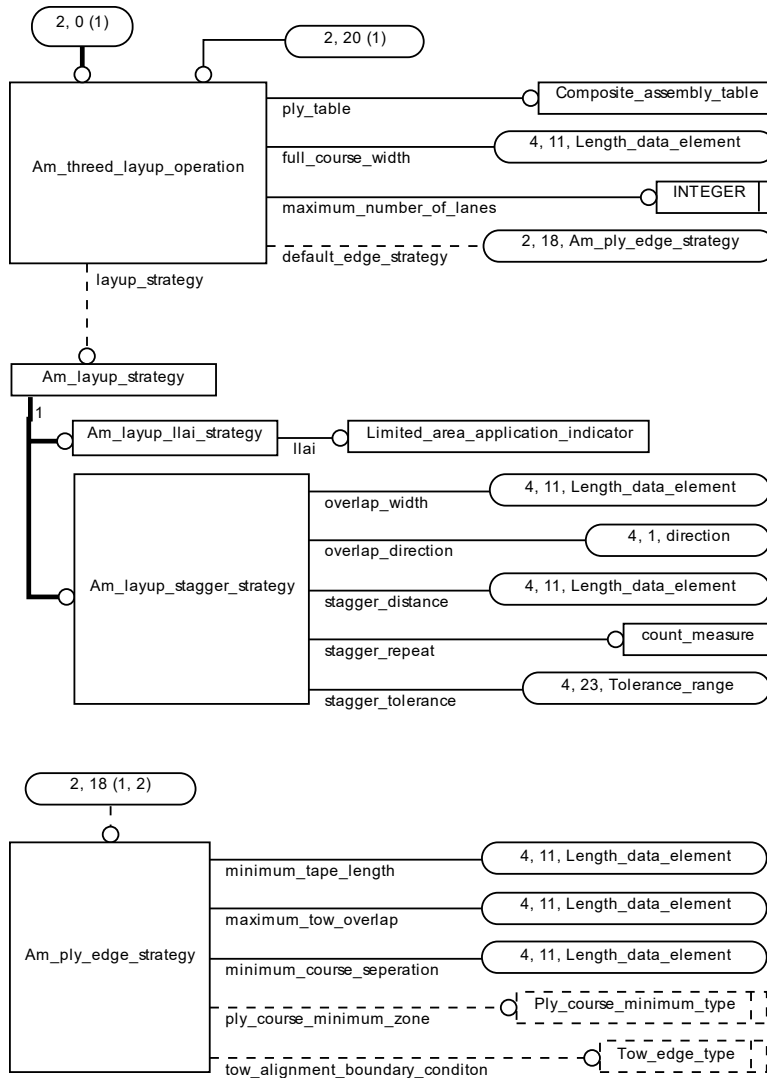
3D Layup Operation

1.19 AM_threed_layup_operation

The AM_threed_layup_operation application object describes process parameters for generating AM_twod_layup_operation application objects.

```
ENTITY Am_threed_layup_operation
SUBTYPE OF (Am_layup_operation);
  ply_table                    : Composite_assembly_table;
  full_course_width            : Length_data_element;
  maximum_number_of_lanes      : INTEGER;
  default_edge_strategy        : OPTIONAL Am_ply_edge_strategy;
  layup_strategy               : OPTIONAL Am_layup_strategy;
END_ENTITY;
```

1.19.1 ply table

the composite assembly table defining the plys to be laid.

1.19.2 full_course_width

the width of the course if all the lanes are active.

1.19.3 maximum_number_of_lanes

the maximum number of lanes allowed in the tow.

NOTE: The number of active lanes is varied between courses to manage stagger. The maximum defines how lanes are addressed when tapes are cut and restarted.

1.19.4 default_edge_strategy

default strategy for any assoicated am_twod_layup_operations when more specific information is not given.

1.19.5 layup_strategy

strategy information for planning am_twod_layup_operations.

1.20 AM_layup_strategy

The AM_layup_strategy application object defines a strategy for generating layup paths across multiple layers.

```
ENTITY Am_layup_strategy
ABSTRACT SUPERTYPE OF (ONEOF (Am_layup_llai_strategy, Am_layup_stagger_strategy));
END_ENTITY;
```

1.21 AM_layup_llai_strategy

The AM_layup_llai_strategy application object defines an engineering specification for the stagger and overlap strategy.

```
ENTITY Am_layup_llai_strategy
SUBTYPE OF (Am_layup_strategy);
   llai       : Limited_length_area_indicator;
END_ENTITY;
```

1.21.1 llai

the engineering information used to control the stagger and overlap strategy.

1.22 AM_layup_stagger_strategy

The AM_layup_stagger_strategy application object defines a stagger and overlap strategy including how many layers are required before a splice can repeat.

```
ENTITY Am_layup_stagger_strategy
SUBTYPE OF (Am_layup_strategy);
  overlap_width     : Length_data_element;
  overlap_direction : direction;
  stagger_distance  : Length_data_element;
  stagger_repeat    : count_measure;
  stagger_tolerance : Tolerance_range;
END_ENTITY;
```

1.22.1 overlap_width

the width of the overlap between courses.

1.22.2 overlap_direction

the direction of the overlap.
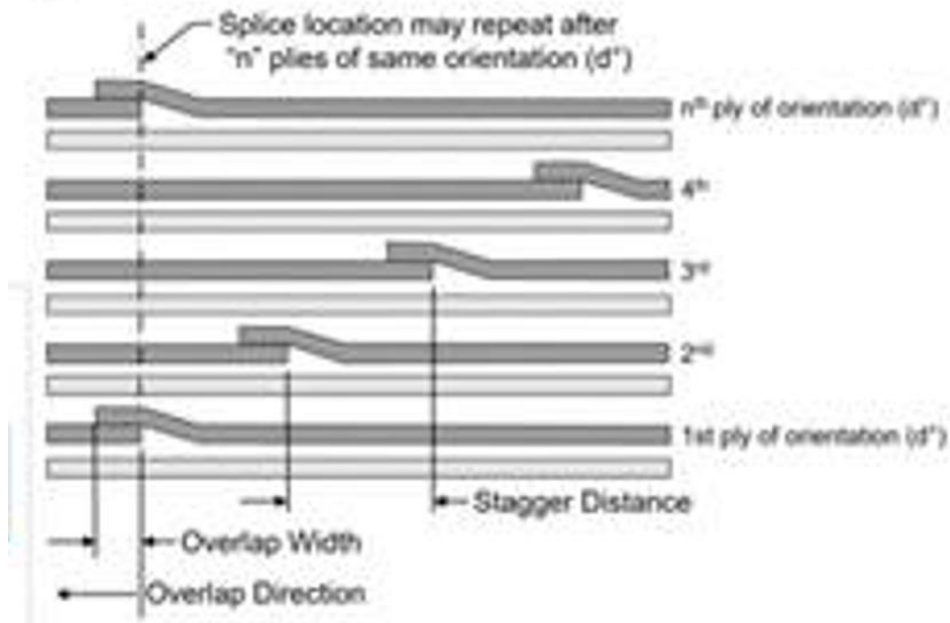
1.22.3 stagger_distance

the distance between overlaps on consecutive layers.

1.22.4 stagger_repeat

the number of layers before a stagger repeats.

1.22.5 stagger_tolerance

the range allowed for the distance between the last tape of one couse and the first tape of the next course.

Splice location may repeat after "n" plies of same orientation (d°)

nth ply of orientation (d°)

4th

3rd

2nd

1st ply of orientation (d°)

Stagger Distance

Overlap Width

Overlap Direction

Stagger Strategy for a sequence of layers

2 Composite Mapping Specification

2.1 AM_LAYUP_OPERATION

```
AIM element: additive_type_operation
Source:      10303-238
Reference path:
additive_type_operation <=
machining_operation <=
action_method
{ ( action_method.description = 'layup oned' )
  ( action_method.description = 'layup twod' )
  ( action_method.description = 'layup threed' ) }
```

2.2 CUT_TAPE_FUNCTION

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

2.2.1 lane_number

```
AIM element: literal_number.the_value
Source:      13584-20
Reference path:
machining_functions <=
action_method
characterized_action_definition = action_method
characterized_action_definition <-
action_property.definition
{ action_property.name = 'lane number' }
action_property <-
action_property_representation.property
action_property_representation
action_property_representation.representation ->
representation
representation.items[i] ->
representation_item =>
integer_representation_item <=
int_literal <=
literal_number
literal_number.the_value
```

2.2.2 cut_angle

```
AIM element: plane_angle_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 = 'cut 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
```

2.3 START_TAPE_FUNCTION

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

```
{ action_method.description = 'start tape' }
```

2.3.1 lane_number

```
AIM element: literal_number.the_value
Source:       13584-20
Reference path:
machining_functions <=
action_method
characterized_action_definition = action_method
characterized_action_definition <-
action_property.definition
{ action_property.name = 'lane number' }
action_property <-
action_property_representation.property
action_property_representation
action_property_representation.representation ->
representation
representation.items[i] ->
representation_item =>
integer_representation_item <=
int_literal <=
literal_number
literal_number.the_value
```

2.4 START_ALL_TAPE_FUNCTION

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

2.5 COMPACTION_ROLLER_COOLING_ON_FUNCTION

```
AIM element: machining_functions
Source:       10303-238
Reference path:
machining_functions <=
action_method
{ action_method.description = 'compaction roller cooling on' }
```

2.6 COMPACTION_ROLLER_COOLING_OFF_FUNCTION

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

```
action_method
{ action_method.description = 'compaction roller cooling off' }
```

2.7 COMPACTION_FORCE_FUNCTION

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

2.7.1 force

```
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 = 'force' }
 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 }
```

2.8 HIGH_HEAT_FUNCTION

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

2.8.1 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 }
```

2.9 LOW_HEAT_FUNCTION

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

2.9.1 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 }
```

2.10 NO_HEAT_FUNCTION

```
AIM element: machining_functions
Source:      10303-238
Reference path:
machining_functions <=
action_method
{ action_method.description = 'no heat' }
```

2.11 TOW_TENSION_FUNCTION

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

2.11.1 new_tension

```
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 = 'tension' }
 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 HIGH_TOW_TENSION_FUNCTION

```
AIM element: machining_functions
```

```
Source:       10303-238
Reference path:
machining_functions <=
action_method
{ action_method.description = 'high tow tension' }
```

2.12.1 new_tension

```
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 = 'tension' }
 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 LOW_TOW_TENSION_FUNCTION

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

2.13.1 new_tension

```
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 = 'tension' }
```

```
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_TECHNOLOGY

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

2.15 AM_LAYUP_TECHNOLOGY

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

2.15.1 head_feedrate

```
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 = 'head feedrate' }
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 }
```

2.15.2 tape_feedrate

```
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 = 'tape feedrate' }
 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 }
```

2.15.3 active_lanes

```
AIM element: literal_number.the_value
Source:        13584-20
Reference path:
machining_technology <=
action_method
characterized_action_definition = action_method
characterized_action_definition <-
action_property.definition
{ action_property.name = 'active lanes' }
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 = set_representation_item
set_representation_item[i] ->
```

```
representation_item =>
integer_representation_item <=
int_literal <=
literal_number
literal_number.the_value
```

2.15.4 tape_width

```
AIM element: length_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 = 'tape 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
```

2.15.5 course_direction

```
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 = 'course direction' }
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 = 'forward' )
(descriptive_representation_item.description = 'backward' ) }
```

2.16 AM_ONED_LAYUP_OPERATION

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

2.16.1 am_oned_layup_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
```

2.16.2 am_oned_layup_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
```

2.16.3 am_oned_layup_operation to am_twod_layup_operation (as its_twod_operation)

```
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
```

2.17 AM_TWOD_LAYUP_OPERATION

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

2.17.1 ply_type

```
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 = 'ply type' }
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 = 'ply piece' )
(descriptive_representation_item.description = 'ply whole' ) }
```

2.17.2 ply_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 = 'ply 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
```

2.17.3 ply_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 = 'ply 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
```

2.17.4 ply_edge_tolerance

```
AIM element: shape_dimension_representation
Source:        10303-47
Reference path:
additive_type_operation <=
machining_operation <=
action_method
characterized_action_definition = action_method
characterized_action_definition <-
action_property.definition
{ action_property.name = 'ply edge tolerance' }
action_property <-
action_property_representation.property
action_property_representation
action_property_representation.representation ->
```

```
representation =>
shape_dimension_representation
```

2.17.5 ply_edge_allowance

```
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 = 'ply edge allowance' }
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
```

2.17.6 am_twod_layup_operation to ply_shape (as ply_basis)

```
AIM element: PATH
Reference path:
additive_type_operation <=
machining_operation <=
action_method <-
action_method_assignment.assigned_action_method
{ action_method_assignment.role ->
action_method_role
action_method_role.name = 'ply basis' }
action_method_assignment =>
applied_action_method_assignment
applied_action_method_assignment.items[i] ->
action_method_items
action_method_items = shape_aspect
shape_aspect
```

2.17.7 engineering_ply_surface

```
AIM element: open_shell
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 = 'engineering ply surface' }
action_property <-
action_property_representation.property
action_property_representation
action_property_representation.representation ->
representation
representation.items[i] ->
representation_item =>
topological_representation_item =>
connected_face_set =>
open_shell
```

2.17.8 engineering_outer_boundary

```
AIM element: composite_curve
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 = 'engineering outer boundary' }
action_property <-
action_property_representation.property
action_property_representation
action_property_representation.representation ->
representation
representation.items[i] ->
representation_item =>
geometric_representation_item =>
curve =>
bounded_curve =>
composite_curve
```

2.17.9 engineering_inner_boundaries

```
AIM element: composite_curve
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 = 'engineering inner boundaries' }
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 =>
curve =>
bounded_curve =>
composite_curve
```

2.17.10   am_twod_layup_operation to direction_select (as engineering_rosette)

```
AIM element: PATH
Reference path:
additive_type_operation <=
machining_operation <=
action_method
characterized_action_definition = action_method
characterized_action_definition <-
action_property.definition
{ action_property.name = ' manufacturing rosette' }
action_property <-
action_property_representation.property
action_property_representation
action_property_representation.representation ->
representation
representation.items[i] ->
representation_item =>
{ (geometric_representation_item =>
cartesian_11)
(geometric_representation_item =>
curve_11)
(geometric_representation_item =>
cylindrical_11)
(geometric_representation_item =>
direction)
(geometric_representation_item =>
point_array)
(geometric_representation_item =>
polar_11)
(user_defined_11) }
```

2.17.11   manufacturing_ply_surface

```
AIM element: open_shell
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 = ' manufacturing ply surface' }
action_property <-
action_property_representation.property
action_property_representation
action_property_representation.representation ->
representation
representation.items[i] ->
representation_item =>
topological_representation_item =>
connected_face_set =>
open_shell
```

2.17.12 manufacturing_outer_boundary

```
AIM element: composite_curve
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 = ' manufacturing outer boundary' }
action_property <-
action_property_representation.property
action_property_representation
action_property_representation.representation ->
representation
representation.items[i] ->
representation_item =>
geometric_representation_item =>
curve =>
bounded_curve =>
composite_curve
```

2.17.13 manufacturing_inner_boundaries

```
AIM element: composite_curve
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 = ' manufacturing inner boundaries' }
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 =>
curve =>
bounded_curve =>
composite_curve
```

2.17.14 am_twod_layup_operation to direction_select (as manufacturing_rosette)

```
AIM element: PATH
Reference path:
additive_type_operation <=
machining_operation <=
action_method
characterized_action_definition = action_method
characterized_action_definition <-
action_property.definition
{ action_property.name = ' manufacturing rosette' }
action_property <-
action_property_representation.property
action_property_representation
action_property_representation.representation ->
representation
representation.items[i] ->
representation_item =>
{ (geometric_representation_item =>
cartesian_11)
(geometric_representation_item =>
curve_11)
(geometric_representation_item =>
cylindrical_11)
(geometric_representation_item =>
direction)
(geometric_representation_item =>
point_array)
(geometric_representation_item =>
polar_11)
(user_defined_11) }
```

2.17.15   am_twod_layup_operation to am_ply_edge_strategy (as its_edge_strategy)

```
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 = 'edge' }
action_method_relationship.related_method ->
action_method =>
machining_strategy =>
additive_type_strategy
```

2.17.16   am_twod_layup_operation to am_threed_layup_operation (as its_threed_operation)

```
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
```

2.18 AM_PLY_EDGE_STRATEGY

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

2.18.1 minimum_tape_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 = 'minimum tape 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
```

2.18.2 maximum_tow_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 = 'maximum tow 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
```

2.18.3 minimum_course_seperation

```
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 = 'minimum course seperation' }
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
```

2.18.4 ply_course_minimum_zone

```
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 = 'ply course minimum zone' }
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 = 'right aligned' )
(descriptive_representation_item.description = 'left aligned' )
(descriptive_representation_item.description = 'centered' ) }
```

2.18.5 tow_alignment_boundary_conditon

```
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 = 'tow alignment boundary condition' }
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 = 'half' )
(descriptive_representation_item.description = 'full' )
(descriptive_representation_item.description = 'none' ) }
```

2.19 AM_THREED_LAYUP_OPERATION

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

2.19.1 am_threed_layup_operation to composite_assembly_table (as ply_table)

```
AIM element: PATH
Reference path:
additive_type_operation <=
machining_operation <=
action_method <-
action_method_assignment.assigned_action_method
{ action_method_assignment.role ->
action_method_role
action_method_role.name = 'ply basis' }
action_method_assignment =>
applied_action_method_assignment
applied_action_method_assignment.items[i] ->
action_method_items
action_method_items = product_definition
product_definition =>
laminate_table =>
part_laminate_table =>
composite_assembly_table
```

2.19.2 full_course_width

```
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 = 'full course 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
```

2.19.3 maximum_number_of_lanes

```
AIM element: count_measure
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 = 'maximum number of lanes' }
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
```

2.19.4 am_threed_layup_operation to am_ply_edge_strategy (as default_edge_strategy)

```
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 = 'default edge' }
action_method_relationship.related_method ->
action_method =>
machining_strategy =>
additive_type_strategy
```

2.19.5 am_threed_layup_operation to am_layup_strategy (as layup_strategy)

```
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 = 'layup' }
action_method_relationship.related_method ->
action_method =>
machining_strategy =>
additive_type_strategy
```

2.20 AM_LAYUP_STRATEGY

```
AIM element: additive_type_strategy
Source:       10303-238
Reference path:
additive_type_strategy <=
machining_strategy <=
action_method
{ (action_method.description = 'layup llai')
(action_method.description = 'layup stagger') }
```

2.21 AM_LAYUP_LLAI_STRATEGY

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

2.21.1 am_layup_llai_strategy to limited_length_area_indicator (as llai)

```
AIM element: PATH
Reference path:
additive_type_strategy <=
machining_strategy <=
action_method <-
action_method_assignment.assigned_action_method
{ action_method_assignment.role ->
action_method_role
action_method_role.name = 'llai' }
action_method_assignment =>
applied_action_method_assignment
applied_action_method_assignment.items[i] ->
```

```
action_method_items
action_method_items = product_definition
product_definition =>
limited_length_area_indicator
```

2.22 AM_LAYUP_STAGGER_STRATEGY

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

2.22.1 overlap_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 = 'overlap 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
```

2.22.2 overlap_direction

```
AIM element: direction
Source:        10303-42
Reference path:
additive_type_strategy <=
machining_strategy <=
action_method
characterized_action_definition = action_method
characterized_action_definition <-
action_property.definition
{ action_property.name = 'overlap direction' }
action_property <-
```

```
action_property_representation.property
action_property_representation
action_property_representation.representation ->
representation
representation.items[i] ->
representation_item =>
geometric_representation_item <=
direction
```

2.22.3 stagger_distance

```
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 = 'stagger distance' }
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
```

2.22.4 stagger_repeat

```
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 = 'stagger repeat' }
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
```

2.22.5 stagger_tolerance

```
AIM element: shape_dimension_representation
Source:      10303-47
Reference path:
additive_type_strategy <=
machining_strategy <=
action_method
characterized_action_definition = action_method
characterized_action_definition <-
action_property.definition
{ action_property.name = 'ply edge tolerance' }
action_property <-
action_property_representation.property
action_property_representation
action_property_representation.representation ->
representation =>
shape_dimension_representation
```

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;
(*
```

4   Change Log

2024-03-31 – Updated to include reference to LLAI strategy in module 1854.

2024-03-24 – Updated for model revisions made at WG15 Renton meeting in preparation for CIB/CD review.