CAx-IF Recommended Practices

for

Composite Materials

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Preface

This document is to be a supplement to the existing AP 203 Recommended Practices document, and is an excerpt from the existing AP 209 Recommended Practices document. Both documents were previously published by PDES, Inc.

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1 Introduction

This Recommended Practices document has been prepared as a usage guide for industry. This document assumes that the reader has at least a rudimentary knowledge of both 10303 STEP and its associated AP 203ed2 (10303-203) and AP 209ed2 (10303-209) application domains. The figures in this document are intended to provide a navigational view of portions of the AP with boxes representing entities, lines being relationships, and arrow heads indicating the pointer direction. This document is to be a supplement to the existing AP 203ed2 Recommended Practices document, and is an excerpt from the existing AP 209ed2 Recommended Practices document.

This document will provide pre- and post-processor recommendations where attributes from the conceptual STEP data models may not actually have values in the AP 203ed2 and AP 209ed2 application domains. The terms pre-processor and post-processor refer to the applications that write and read the application data respectively. In these recommendations, the term ‘no standard mapping’ means there is no mapping defined in the AP's ARM-to-AIM mapping table for the data.

2 Using AP 203ed2 and AP209ed2 to represent Composite Material Shape and Structure

This section describes how AP 203ed2 and AP 209ed2 are intended to be used to represent structures made of composite materials. This section will establish examples and limits on some of the data constructs that are not constrained in the Application Interpreted Model (AIM) of the Application Protocols (AP).

2.1 Composite Part and Constituent Representations

A composite part is made of constituents that are laminated in layers to create the part. AP 203ed2 and AP 209ed2 provides specialized product definitions to represent the structural makeup and properties of composite parts.

Ply, `processed_core`, and `filament_laminate` are the basic constituents in composite parts. A ply laminate is a composite part is composed of layers or sequences of plies. A `composite_assembly` is also constructed in layers, except that a composite assembly may have sequences of constituents other than plies, such as processed core, and may contain ply laminates and other composite assemblies as constituents.

2.1.1.1 Composite Part Structural Representation

The structural makeup of a composite part is described by a laminate table. The laminate table exists as one of its two subtypes: part laminate table and zone structural makeup. The part laminate table describes allocation of the physical constituents for the overall laminate, while the zone structural makeup is used to describe the physical constituents for a particular zone, area, or point on the part. The part laminate table and zone structural makeup in turn exist as one of their respective subtypes. The part laminate table is called the ply laminate table for a ply laminate part, and the composite assembly table for a composite assembly part. The zone structural makeup may be a thickness laminate table or percentage laminate table that provides allocation of the composite constituents by thickness or percentage, respectively. A smeared material definition is a special case of zone structural makeup representation, where all the composite constituents across the thickness are lumped together.

Associated with each laminate table is a `shape_representation` for the base surface of the composite part, which includes in its set of items a surface and a direction that specifies the material side. The surface and direction geometric `representation_items` shall be the first and second `representation_items` respectively in the items of this `shape_representation`. The name attribute of the surface `representation_item` is set to `'base_surface'`. A second `shape_representation` may be used to represent the opposing surface that results from the

build-up of material on the base surface, with the name attribute of the surface `representation_item` is set to `'resulting_surface'`. Both surfaces are represented as shape aspects for the laminate table (Figure 1).

NOTE - Figure 1 applies to ply laminate table, composite assembly table, thickness laminate table, percentage laminate table, and smeared material as follows: Ply laminate table and composite assembly table are subtypes of part laminate table, which is in turn a subtype of laminate table. Hence, ply laminate table and composite assembly table inherit all of the attributes of laminate table and part laminate table. Likewise, thickness laminate table, percentage laminate table, and smeared material are subtypes of zone structural makeup, which is in turn a subtype of laminate table. Hence, thickness laminate table, percentage laminate table, and smeared material inherit all of the attributes of laminate table and zone structural makeup. The mapping for these entities are as follows :

laminate table	`product_definition`
part laminate table	`product_definition`
zone structural makeup	`product_definition`
ply laminate table	`ply_laminate_table <= product_definition`
composite assembly table	`composite_assembly_table <= product_definition`
thickness laminate table	`thickness_laminate_table <= product_definition`
percentage laminate table	`percentage_laminate_table <= product_definition`
smeared material	`smeared_material_table <= product_definition`

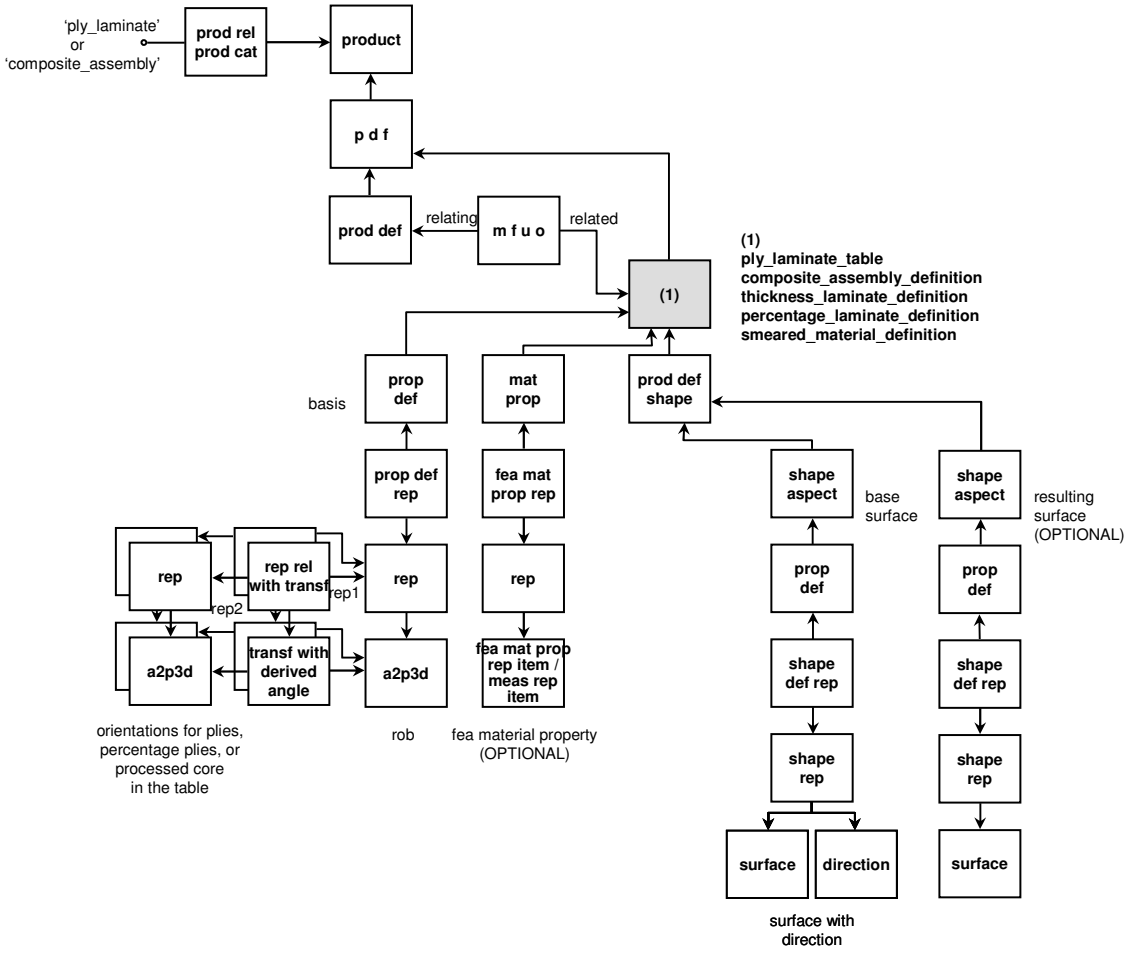


Figure 1: Laminate Table

A laminate table is also characterized by a reinforcement orientation basis (rosette) represented by an `axis2_placement_3d` entity. `Representation_relationship_with_transformation` entities relate the reinforcement orientation basis to the corresponding orientation representations for each ply or composite constituent in the table. The transformation operator for the relationship is a complex entity of `item_defined_transformation`, and two composites specific subtype entities. One of these entities is either the `laid_defined_transformation` or `draped_defined_orientation`. The other is the `transformation_with_derived_angle`, which provides a means for calculating the angle between the reinforcement orientation basis and the orientation for the composite constituent in the table.

The material properties to be used in the finite element analysis of a composite part may be specified by associating the overall properties to the laminate table. To this end, the `fea_material_property_representation` entity is used to relate the material property representation to the `product_definition` for the laminate table.

2.1.1.1.1 Ply Laminate Table

The ply laminate table that describes the sequencing of ply layers for a ply laminate is represented by a `ply_laminate_table` in AP 203 and AP 209. The `product_definition` for a ply laminate part or constituent is related to the ply laminate table by a `make_from_usage_option`. Each layer in the laminate is represented by a `ply_laminate_sequence_definition`. The first `ply_laminate_sequence_definition` in the table is related to the `ply_laminate_table` by a `next_assembly_usage_occurrence` entity. The `ply_laminate_table` is the `relating_product_definition`, and the `ply_laminate_sequence_definition` is the `related_product_definition` in this relationship. Subsequent layers in the ply laminate are likewise related to the preceding layer through `next_assembly_usage_occurrences`, thus forming a chain of `ply_laminate_sequence_definitions` (Figure 2). The `ply_laminate_table` and the associated `ply_laminate_sequence_definitions` all point to the `product_definition_formation` for the ply laminate part.

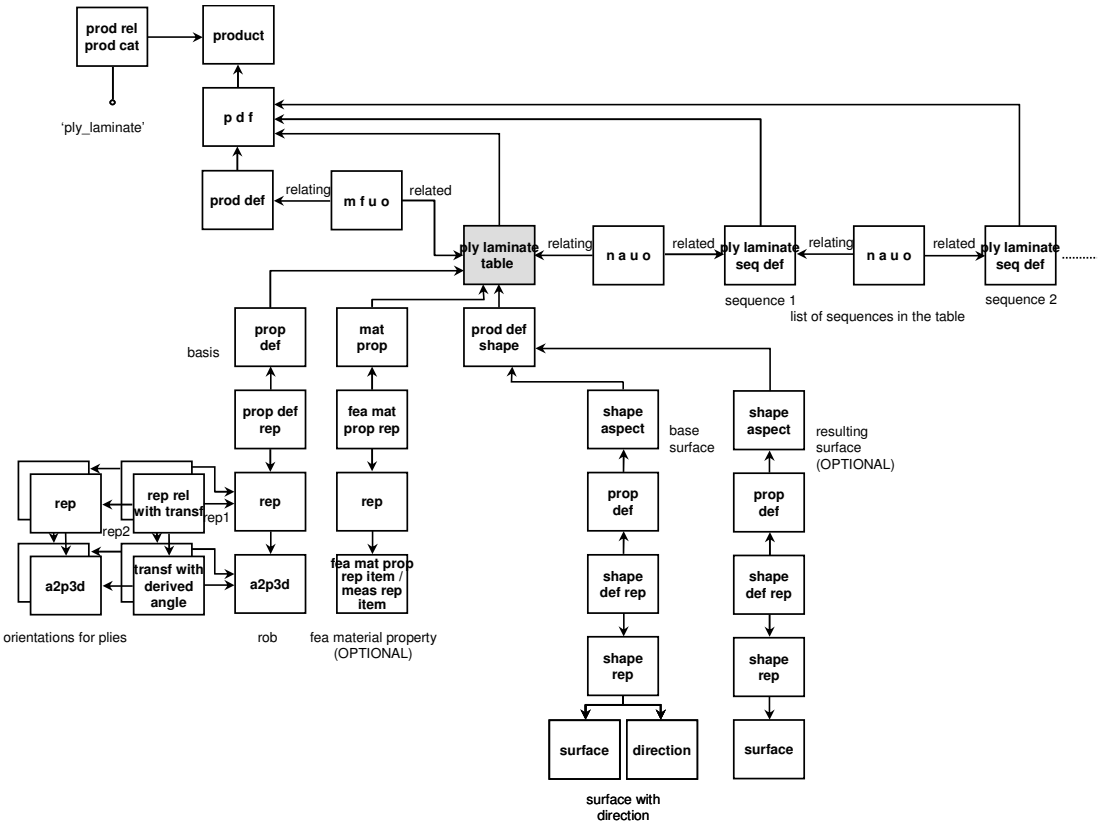


Figure 2: Ply Laminate Table

A layer in a ply laminate may contain one or more plies. Each of the ply `product_definitions` in a sequence are related to the `ply_laminate_sequence_definition` by a `next_assembly_usage_occurrence` entity, forming a tree of ply `product_definitions` (Figure 3).

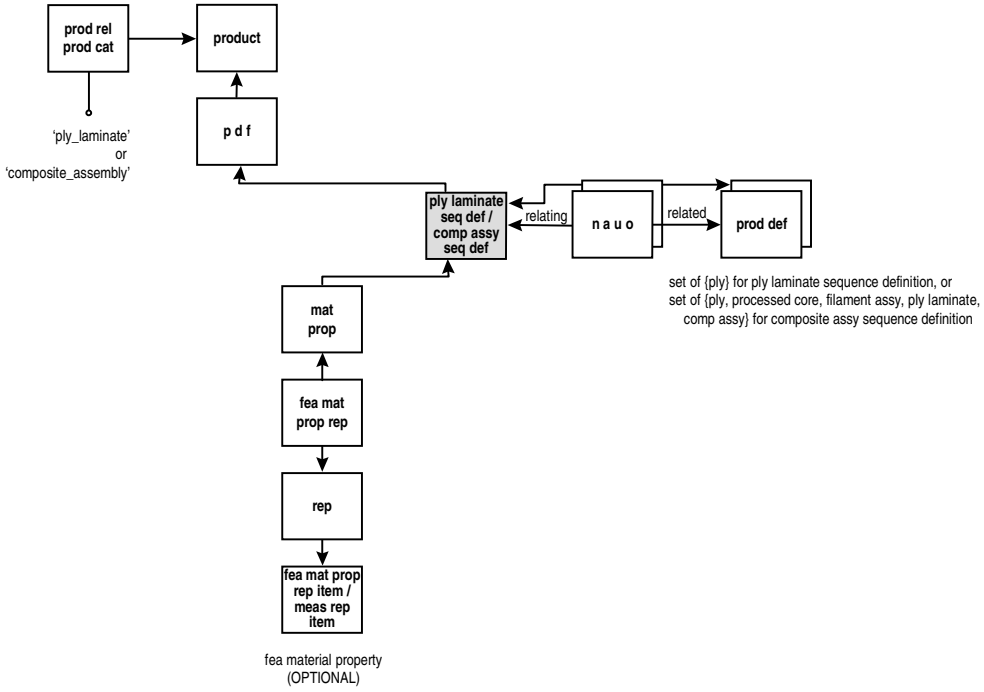


Figure 3: Part Laminate Table Sequence Definitions

The material properties to be used in the finite element analysis of a ply laminate part may be specified by associating the overall properties to the laminate table as discussed above (see Section 2.1.1.1), or by associating the properties to each sequence in the `ply_laminate_table`. The `fea_material_property_representation` entity is used to relate the material property representation to a `ply_laminate_sequence_definition`.

2.1.1.1.2 Composite Assembly Table

A composite assembly is similar in structure to a ply laminate, except that a composite assembly may have sequences of constituents other than plies, such as processed core, and may include other assemblies. A composite assembly structure is thus represented by a chain of `composite_assembly_sequence_definitions` headed by a `composite_assembly_table` (Figure 3). The `composite_assembly_table` and the associated `composite_assembly_sequence_definitions` all point to the `product_definition_formation` for the composite assembly part.

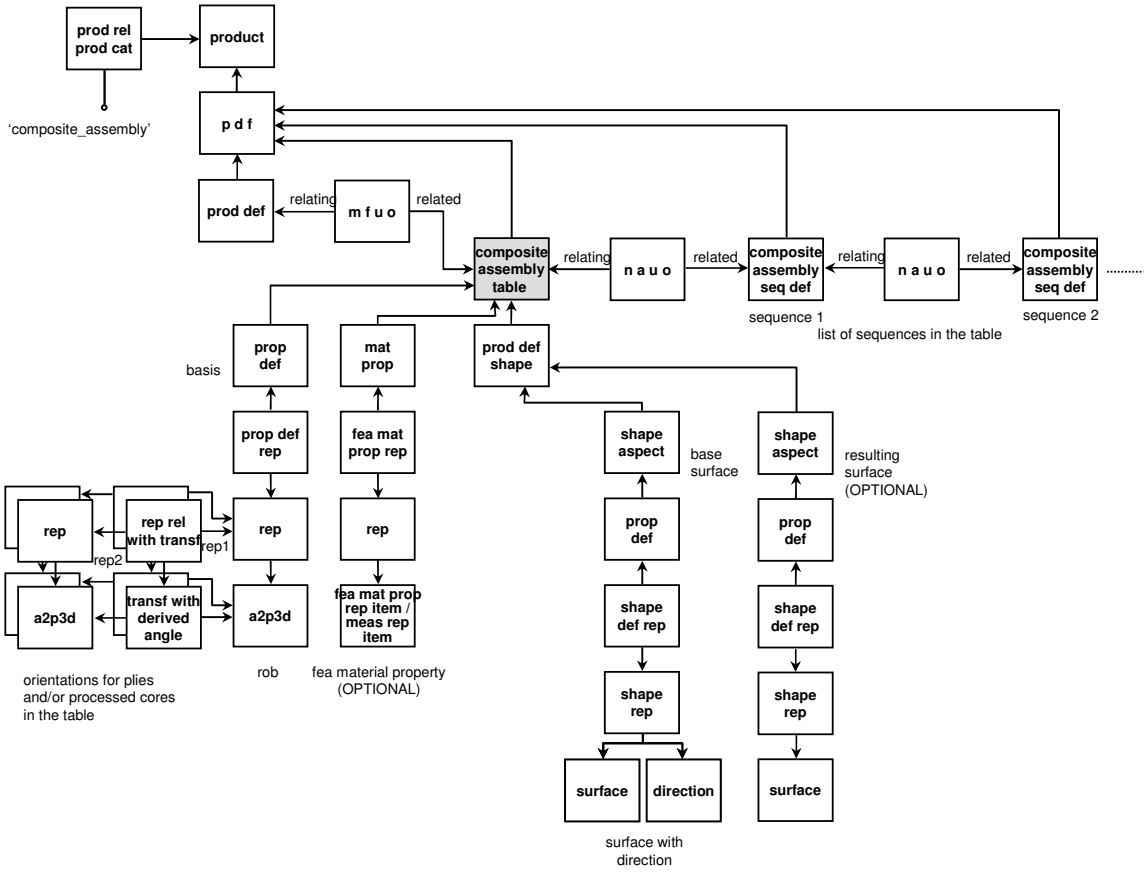


Figure 4: Composite Assembly Table

Like the `ply_laminate_sequence_definition`, the `composite_assembly_sequence_definition` is linked to its composite constituent `product_definitions` through branches of `next_assembly_usage_occurrences` (Figure 3).

The material properties to be used in the finite element analysis of a composite assembly part may be specified by associating the overall properties to the laminate table as discussed above (see Section 2.1.1.1), or by associating the properties to each sequence in the `composite_assembly_table`. The `fea_material_property_representation` entity is used to relate the material property representation to a `composite_assembly_sequence_definition`.

2.1.1.1.3 Thickness Laminate Table

A thickness laminate table, represented by a `thickness_laminate_table`, is used to specify composite constituents that make up a zone of a composite part. A `thickness_laminate_table` is structured similar to a `composite_assembly_table` as can be seen in Figure 5. Since each layer or sequence is local, the corresponding 'sequence' definition contains a single composite constituent that is either a `ply`, `processed_core`, or a `filament_laminate`. The `next_assembly_usage_occurrence.relating_product_definition` identifies the `thickness_laminate_table` and the `next_assembly_usage_occurrence.related_product_definition` identifies the first product in the sequence. Subsequent products are ordered in the same manner using `next_assembly_usage_occurrence` entities. In addition to the base surface and the optional resulting surface, the zone edge shape may be specified for a thickness laminate table using a `shape_representation`.

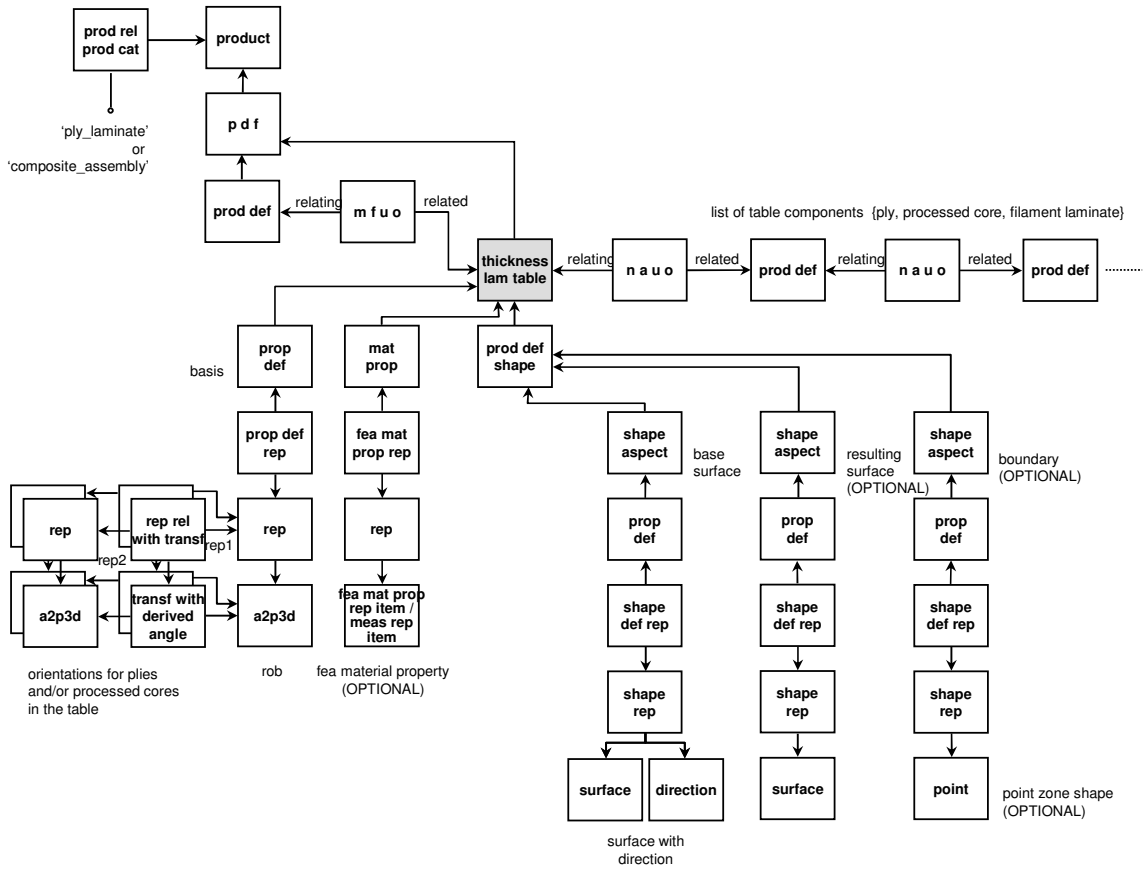


Figure 5: Thickness Laminate Table

When multiple thickness laminate tables intersect, that is, share constituent parts, it may be necessary to distinguish the chain of `next_assembly_usage_occurrence` entities belonging to a `thickness_laminate` table form that belonging to another. This can be accomplished by using the same description for all the `next_assembly_usage_occurrence` entities in a chain that is consistent with the description for the `thickness_laminate_table` at the top of the chain. This is illustrated in Figure 6.

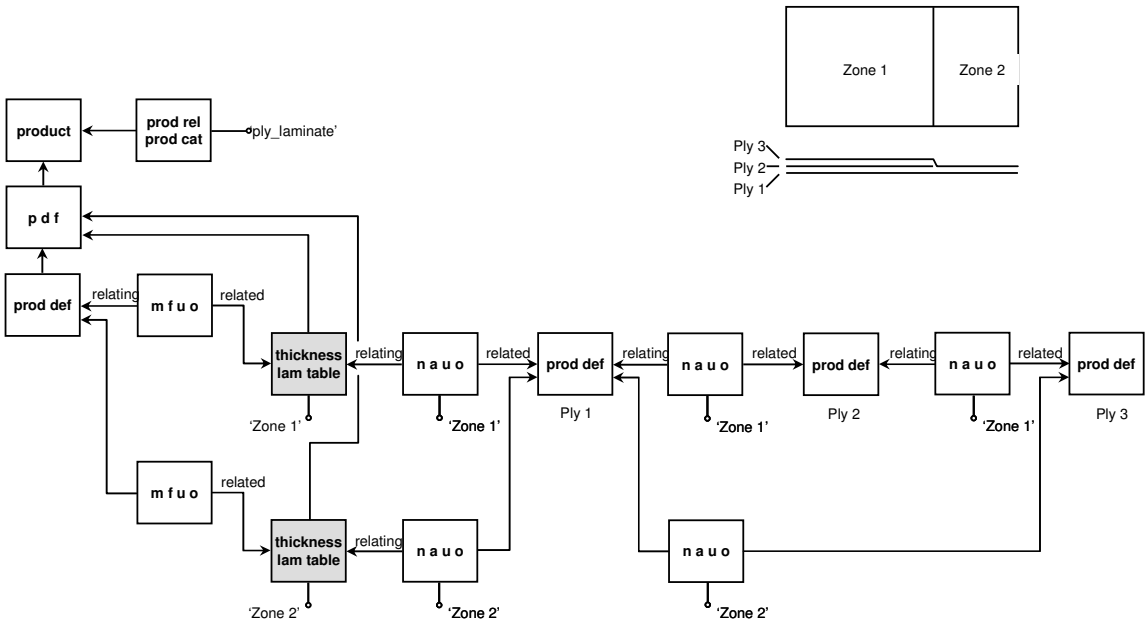


Figure 6: Multiple Zones Sharing Plies

2.1.1.1.4 Percentage Laminate Table

A percentage laminate table, represented by a `percentage_laminate_table`, is used to specify the percentages of the composite constituents at a point or area of the part. The table components are percentage plies, represented by `percentage_ply_definition` entities. Each `percentage_ply_definition` is related to the `percentage_laminate_table` by a `next_assembly_usage_occurrence` entity. A `shape_representation` may be used to represent the edge or point zone shape for the percentage laminate table. A `representation` is used to specify the total thickness for the zone. The `representation` shall have a `measure_representation_item` that has a `length_measure_with_unit` in its set of items (Figure 7).

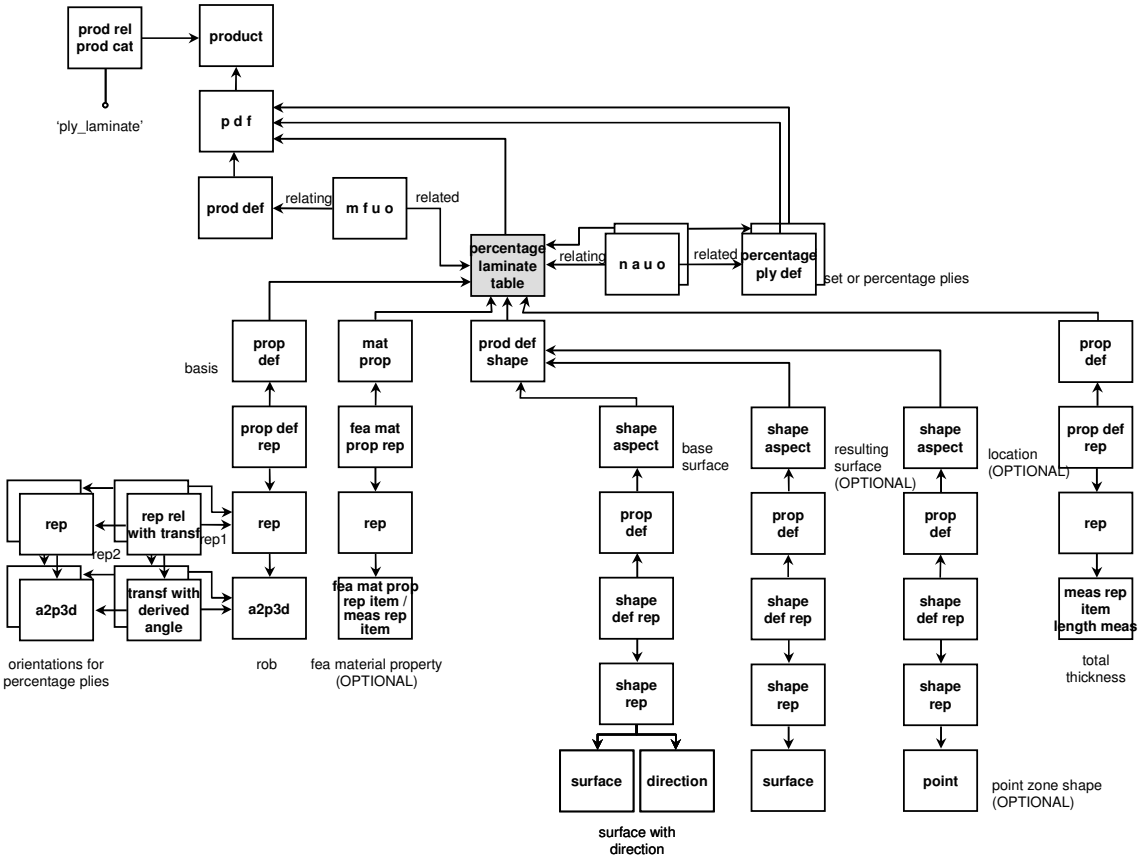


Figure 7: Percentage Laminate Table

2.1.1.1.4.1 Percentage Ply

A `percentage_ply_definition` is the 'composite constituent' for a percentage laminate table (Figure 8). A `make_from_usage_option` entity is used to relate the `percentage_ply_definition` to its stock material `product_definition`, which is associated with a product in a `product_related_product_category` with a name of 'filament_assembly', 'discontinuous_fiber_assembly', 'stock_core', 'isotropic_material', or 'anisotropic_material'. The internal makeup of a percentage ply may in turn be specified by one of the zone structural makeup representations.

A percentage ply has a representation to denote its percentage. The representation shall have a `measure_representation_item` that is a `ratio_measure` in its set of items. The volume percents of the `percentage_ply_definitions` in the table shall add up to 100%.

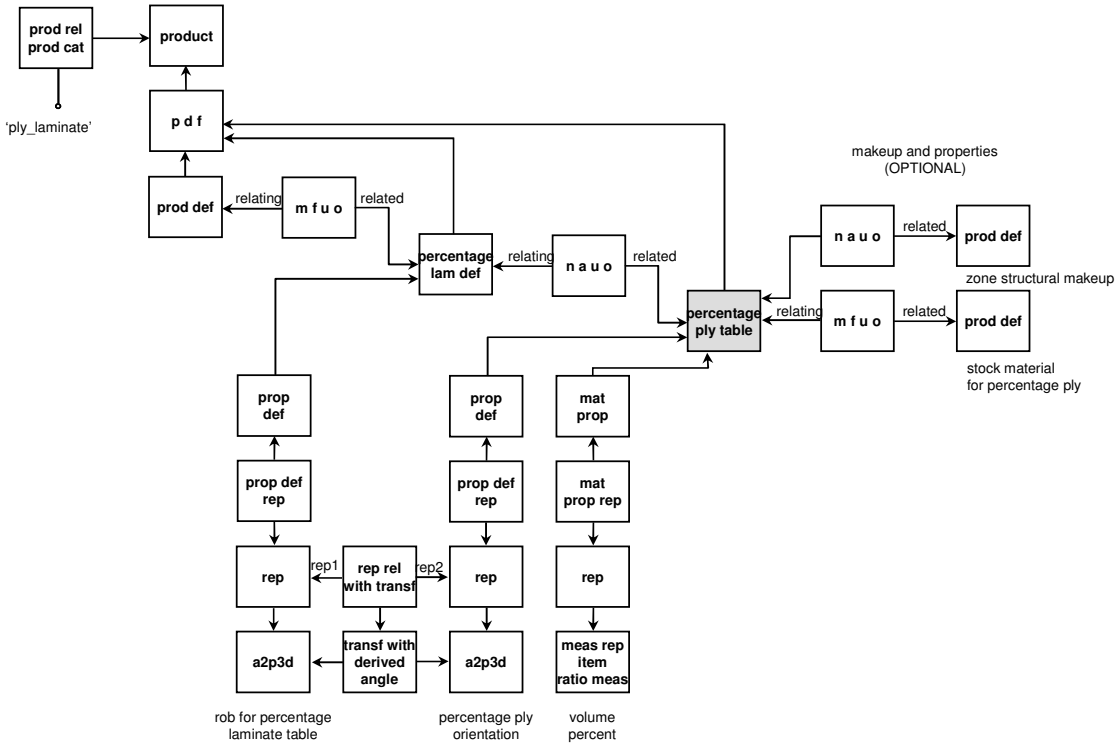


Figure 8: Percentage Ply

A percentage ply has another representation to denote its orientation. The orientation is represented by an `axis2_placement_3d` entity in the set of items of the representation. A `representation_relationship_with_transformation` shall link this representation to the representation for the reinforcement orientation basis of the corresponding percentage laminate table. The `transformation_operator` for this `representation_relationship` shall point to an `item_defined_transformation` that links the corresponding `axis2_placement_3d` entities for the two representations.

2.1.1.1.5 Smeared Material

A `smeared_material_table` is an alternate definition that lumps all the composite constituents together (Figure 9). A `shape_representation` may be used to represent the zone shape for the `smeared_material_table`. A representation is used to the specify the total thickness. If the smeared material definition is used together with a percentage laminate table or a thickness laminate table, the thickness specified for the `smeared_material_table` shall be consistent with that for the `percentage_laminate_table`, or with the sum of thicknesses of the composite constituents in the `thickness_laminate_table`.

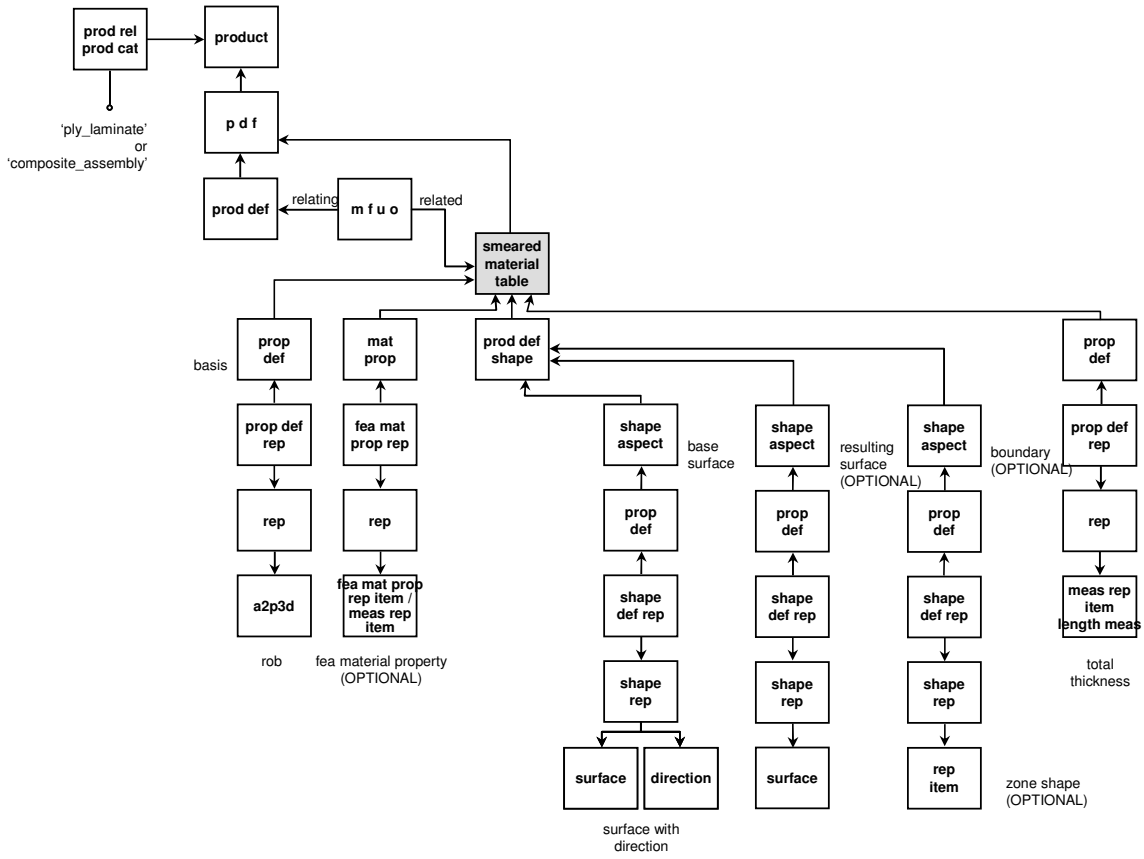
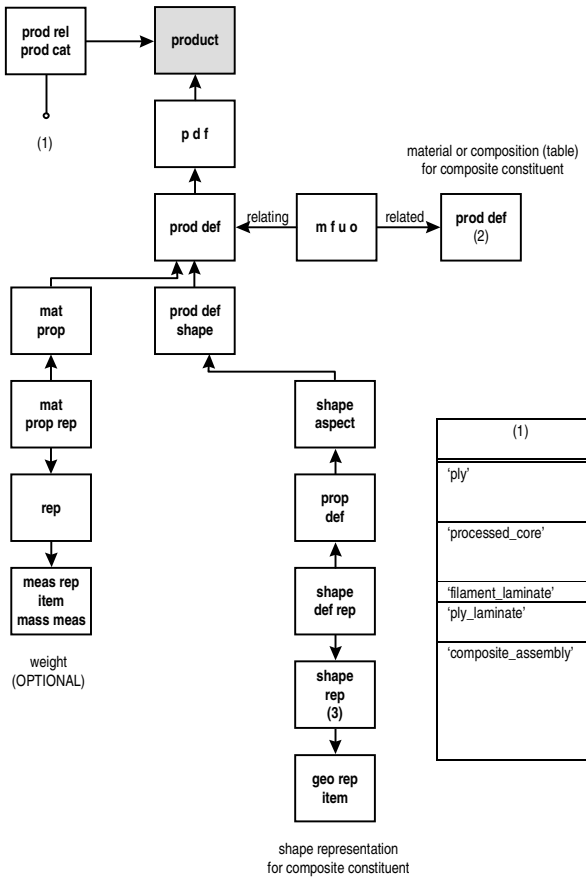


Figure 9: Smeared Material

2.1.1.2 Composite Constituent and Shape Representations

In AP 203 and AP 209, ply, processed core, and filament laminate are the basic composite constituents that are layered to form ply laminates or composite assemblies. Ply laminates and composite assemblies can also be used as composite constituents in a composite assembly.

A composite constituent exists as one of its five subtypes: ply, processed core, filament laminate, ply laminate, and composite assembly. This is indicated by associating the product for the composite constituent with a `product_related_product_category` that has the corresponding name attribute of 'ply', 'processed core', 'filament laminate', 'ply laminate', or 'composite assembly. The material for a composite constituent is specified by a `make_from_usage_option`. The constituent `product_definition` is the `relating_product_definition`, and the material `product_definition` is the `related_product_definition` in this relationship (Figure 10).



(1)	(2) **product_definition** for	(3) **shape_representation**
'ply'	isotropic material filament assembly discontinuous fiber assembly	**comp_sheet_representation**
'processed_core'	stock core	**beveled_sheet_representation** **advanced_boundary_shape_representation** **faceted_ boundary_shape_representation**
'filament_laminate'	filament assembly	**shape_representation for XS**
'ply_laminate'	ply laminate table **(ply_laminate_definition)**	**composite_sheet_representation** **geo_bound_surface_shape_representation**
'composite_assembly'	composite assembly table **(composite_assembly_definition)**	**advanced_ boundary_shape_representation** **faceted_ boundary_shape_representation** **geo_bound_surface_shape_representation** **geo_bound_wireframe_shape_representation** **edge_based_wireframe_shape_representation** **shell_based_wireframe_shape_representation**

Figure 10: Composite Constituents

A composite constituent may have a representation to denote the weight of the constituent. A `material_property_representation` entity is used to link this representation with the `property_definition` subtype `material_property`. The representation shall have a `measure_representation_item` that is a `mass_measure_with_unit` in its set of items.

2.1.1.2.1 Ply

A ply product is associated with a `product_related_product_category` with a name of 'ply' (Figure 11). The ply `product_definition` is related by a `make_from_usage_option` to its stock material `product_definition`, which is associated with a product in a `product_related_product_category` with a name of 'filament_assembly', 'dicscontinuous_fiber_assembly', or 'isotropic_material'.

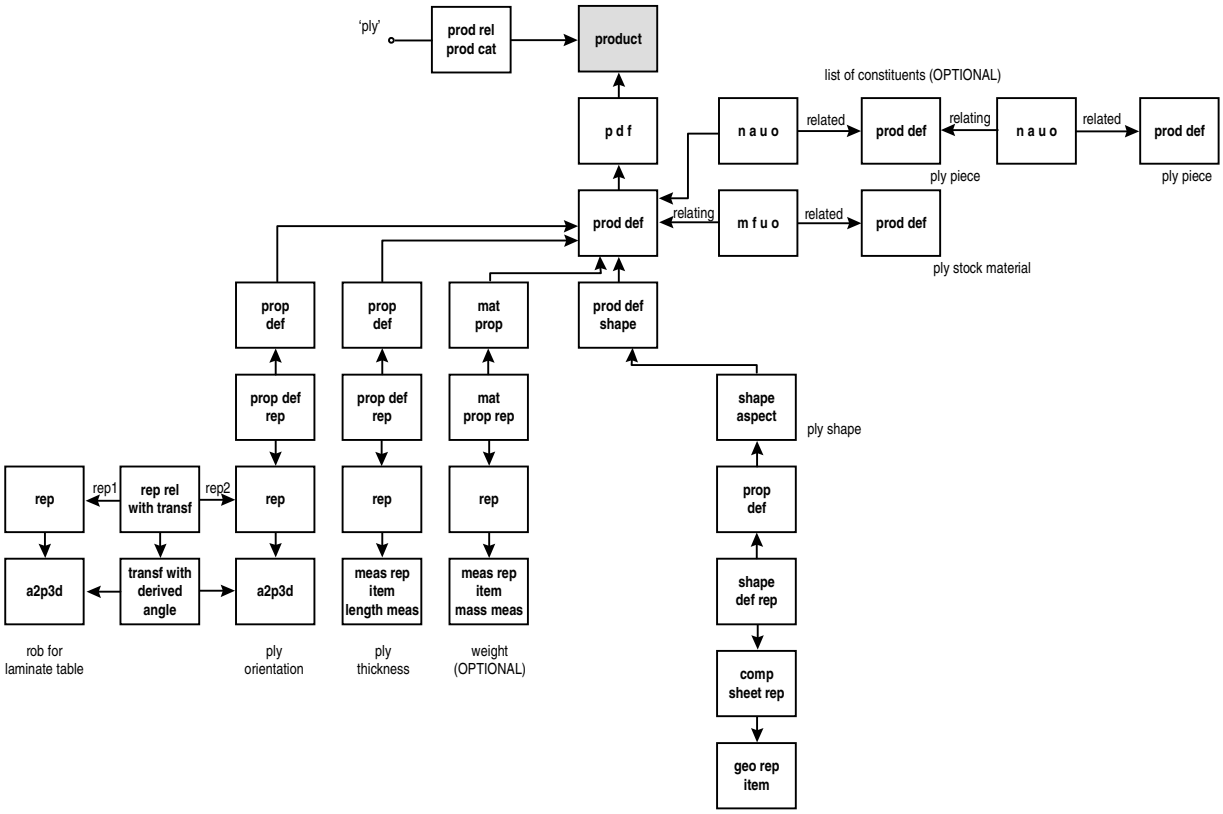


Figure 11: Ply

If two or more ply pieces are combined together in a single layer to make up the ply, then the list of the ply pieces shall be given by a chain of `next_assembly_usage_occurrence` entities. The first `next_assembly_usage_occurrence` in the chain shall have the `product_definition` for the ply as the `relating_product_definition`, and the `product_definition` for the first ply piece in the list as the `related_product_definition`. The second `next_assembly_usage_occurrence` in the chain shall likewise link the `product_definitions` for the first and second ply pieces in the list, and so on.

A ply has a representation to denote its thickness. The representation shall have a `measure_representation_item` that is a `length_measure_with_unit` in its set of items.

A ply has another representation to denote its orientation. The orientation is represented by an `axis2_placement_3d` entity in the set of items of the `representation`. A `representation_relationship_with_transformation` shall link this `representation` to the `representation` for the reinforcement orientation basis of the corresponding laminate table. The `transformation_operator` for this `representation_relationship` shall point to an `item_defined_transformation` that links the corresponding `axis2_placement_3d` entities for the two representations. The `item_defined_transformation` shall be complex entity that is a `transformation_with_derived_angle`, and either a `draped_defined_transformation` or a `laid_defined_transformation`. The `transformation_with_derived_angle` is used to derive the angle between the reinforcement orientation basis and the ply orientation. The third direction of the `axis2_placement_3d` entities representing these two orientations (`transform_item_1` and `transform_item_2`) shall be the same. The ply orientation may be specified explicitly by a direction (which will be the axis direction of the `axis2_placement_3d` for the ply). Alternately, the ply orientation may be specified implicitly through a curve or point path. If a curve is specified, the tangent at any point along the curve will be the axis direction of the `axis2_placement_3d` for the ply. If a `point_path` is specified, the

major and minor directions of the `point_and_vector` entities in the point path will be associated with the axis direction of the `axis2_placement_3d` (see Figure 12).

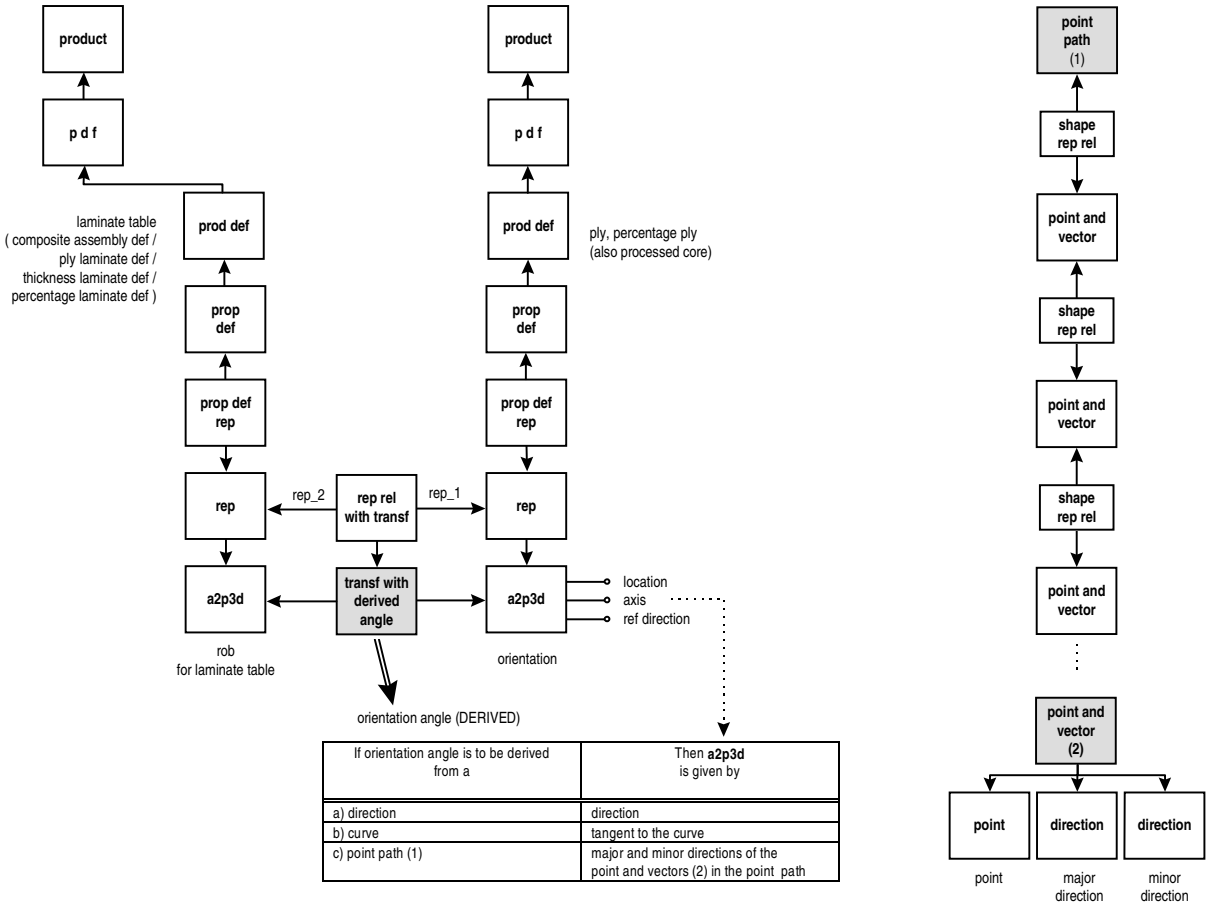


Figure 12: Ply Orientation

A point path is represented in AP 203 and AP 209 by a chain of `point_and_vector` entities, headed by a `point_path`. The `point_path` and `point_and_vector` are both subtypes of `shape_representation`. A `point_and_vector` represents a point and the associated vector pairs on a point path. The first `representation_item` in the `items` of a `point_and_vector` is shall be a `point` entity, the second a `direction` entity representing the major direction, and the third a `direction` entity representing the minor direction.

2.1.1.2.1.1 Ply Shape

The shape of a ply is represented by a `product_definition_shape` entity. `Shape_aspects` that represent various features of the ply shape point to this `product_definition_shape`. The `name` attribute of the `shape_aspect` shall describe the feature that is being represented, such as ‘laid_ply_shape’, ‘basis_surface’, and ‘outer_edge’.

The defining model for a ply shape is given by a `shape_representation` that is a `composite_sheet_representation`, an `advanced_brep_shape_representation`, a `csg_shape_representation`, a `curve_swept_solid_shape_representation`, an `elementary_brep_shape_representation`, or a `faceted_brep_shape_representation`. The `composite_sheet_representation` shall be either a `geometrically_bounded_surface_shape_representation` or a `manifold_surface_shape_representation` (Figure 13).

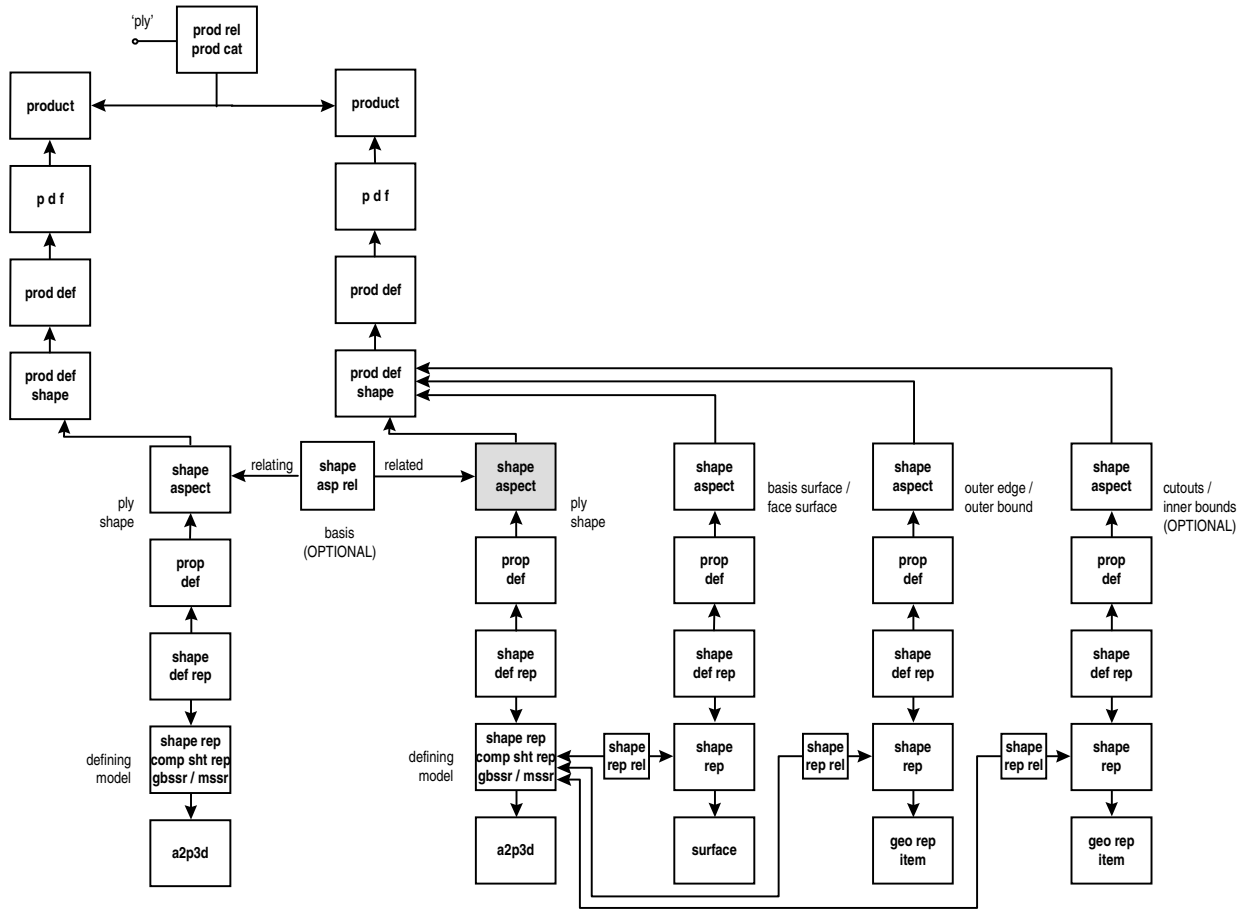


Figure 13: Ply Shape

Associated with the defining model `shape_representation` are the `shape_representations` for: a) the basis or face surface of the ply with a corresponding `shape_aspect.name` of 'basis_surface' or 'face_surface'; b) outer edge or bound of the ply with a corresponding `shape_aspect.name` of 'outer_edge' or 'outer_bound'; and, optionally, c) the cutouts or inner bounds for the ply with a corresponding `shape_aspect.name` of 'cutouts' or 'inner_bounds'. Each of these `shape_representations` is related to the defining model `shape_representation` by a `shape_representation_relationship`.

If the shape of a ply is based on or derived from another ply shape, then this relationship is represented by a `shape_aspect_relationship` between the `shape_aspects` for the defining model `shape_representations` of the two plies. The `name` attribute of the `shape_aspect_relationship` is set to 'basis'.

A ply shape may be one of: laid ply shape, flat pattern ply shape, or projected ply shape. For a laid ply shape, the `name` of the `shape_aspect` for the defining model is set to 'laid_ply_shape'. For a flat_pattern_ply_shape, the `name` of the `shape_aspect` for the defining model is set to 'flat_pattern_ply_shape' (see Figure 14). The wrapup origin on the flat pattern is represented by the `location` attribute of the `placement representation_item` in the items of the flat pattern `shape_representation`. The wrapup origin on the flat pattern is represented by the `location` attribute of the `placement representation_item` in the `items` of the 3D `shape_representation` from which the flat pattern is derived. The `shape_representations` are linked together by a complex entity that is a `flat_pattern_ply_representation_relationship` and a `representation_relationship_with_transformation`. The `rep_1` attribute of the `representation_relationship_with_transformation` represents the 3D shape representation and the `rep_2` attribute is the flat pattern `shape_representation`.

The `transformation_operator` attribute points to the `item_defined_transformation` entity that serves to match the origin points on the flat pattern and surface.

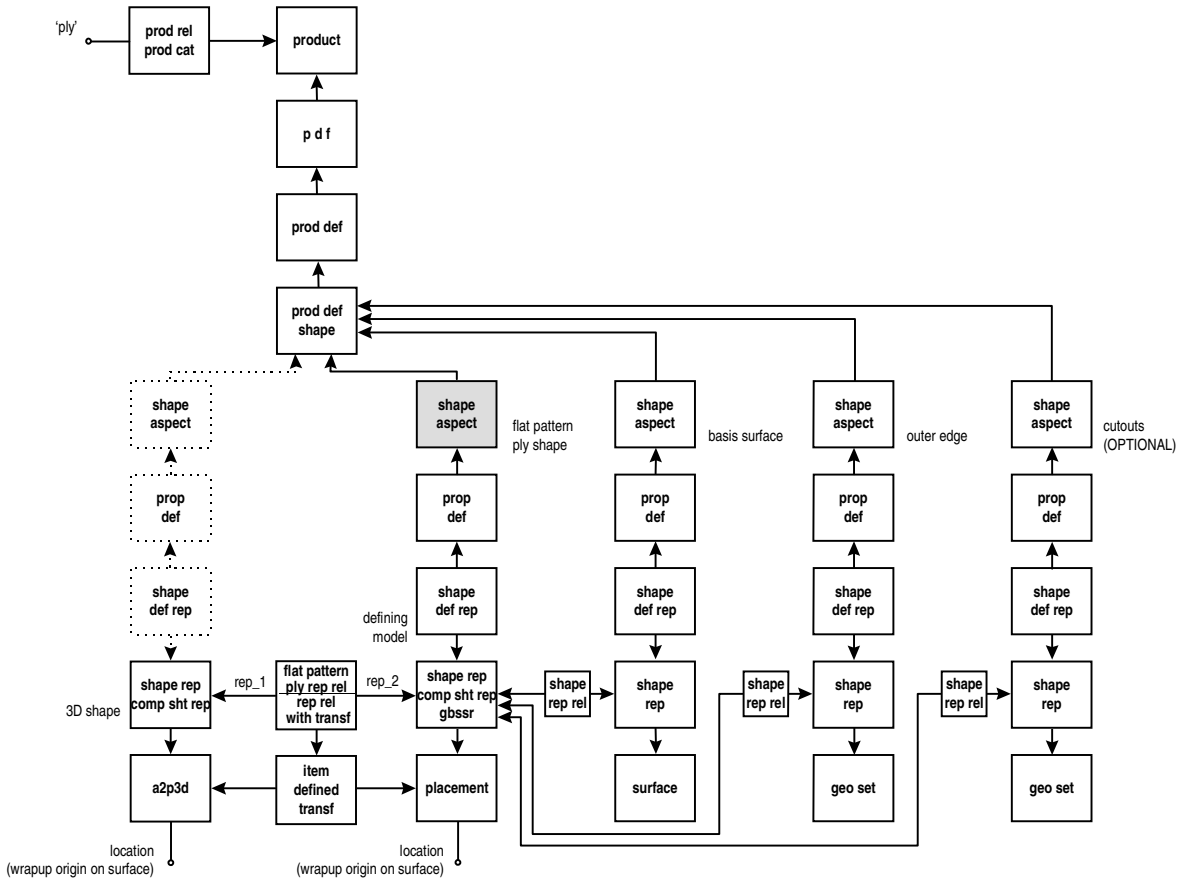


Figure 14: Flat Pattern Ply Shape

In the case of a projected ply shape, the ply shape may be a surface ply shape or a view ply shape depending on whether the ply shape is projected on a surface or a plane. The `name` of the `shape_aspect` for the defining model is set to: 'reference_direction_projected_surface_ply_-shape', 'surface_normal_projected_surface_ply_shape', 'reference_direction_projected_view_-ply_shape', or 'surface_normal_projected_view_ply_shape' based on the projection method. If a direction other than the surface normal is used, a `shape_aspect` representing the projection direction is associated with the `product_definition_shape`, and a `placement` entity referencing the projection direction is included in the set of items of the corresponding `shape_-representation` (see Figure 15).

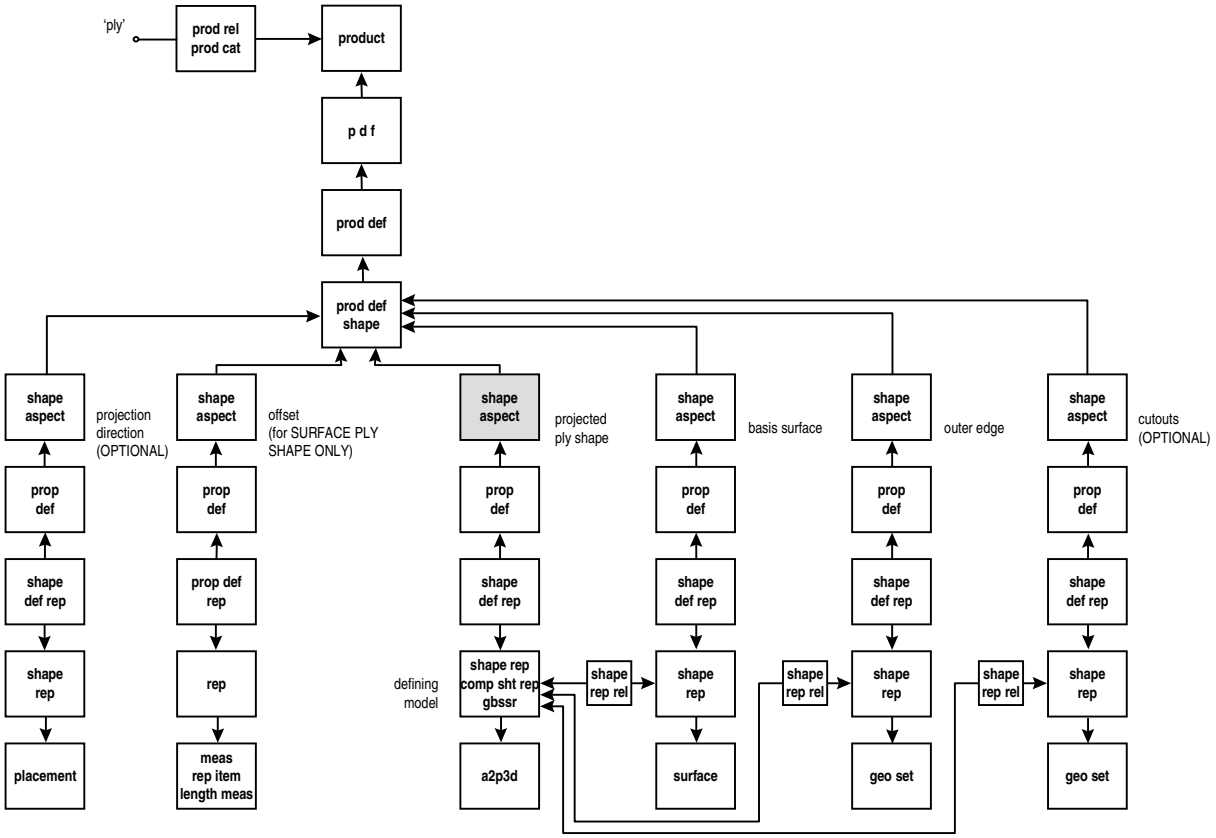


Figure 15: Projected Ply Shape (Surface Ply Shape or View Ply Shape)

For a surface ply shape, the context of the surface is indicated by the description attribute of the `shape_aspect` for the defining model. It is recommended that the description be set to: 'layup_surface', 'outer_mold_line', or 'inner_mold_line'. The offset distance from the layup surface is represented by a separate `shape_aspect`. The corresponding representation shall have a `measure_representation_item` that is a `length_measure_with_unit` in its set of items.

2.1.1.2.2 Processed Core

A processed core product is associated with a `product_related_product_category` with a `name` of 'processed_core' (Figure 16). The processed core `product_definition` is related by a `make_from_usage_option` entity to its stock material `product_definition`, which will be associated with a product in a `product_related_product_category` with a `name` of 'stock_core'.

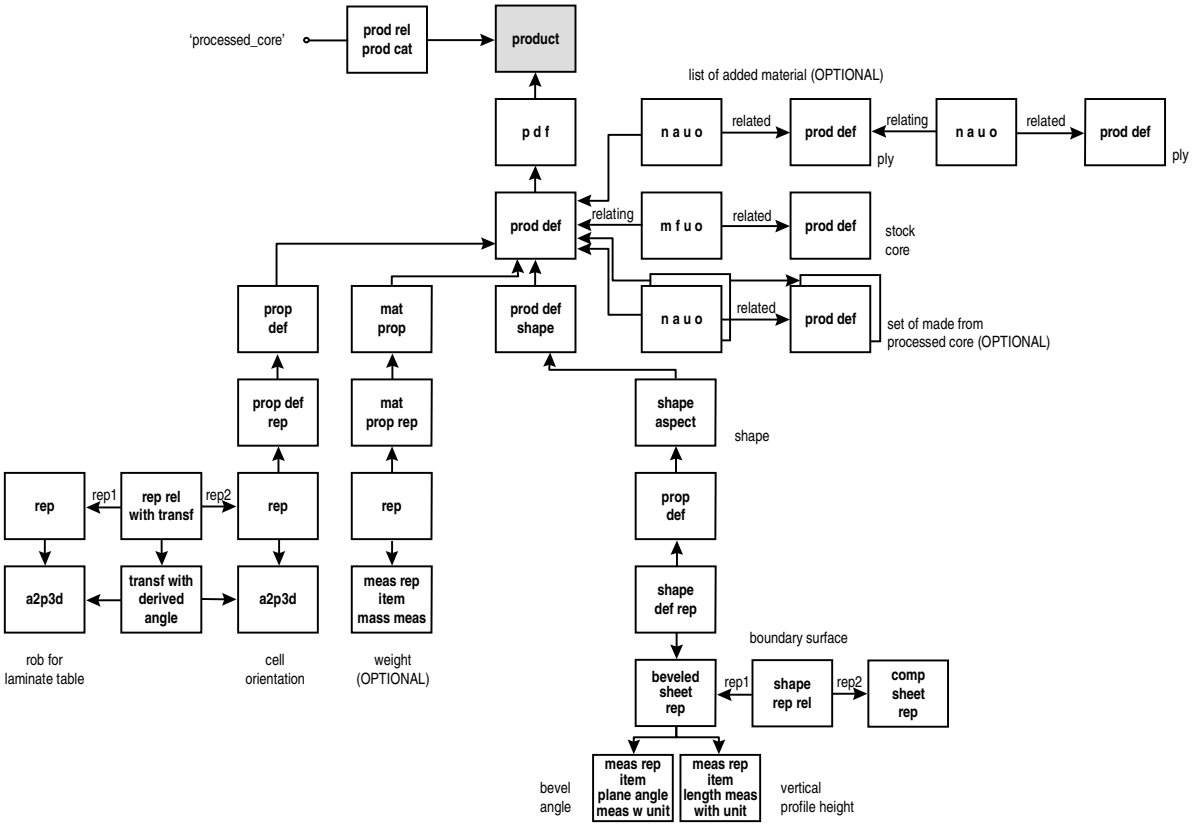


Figure 16: Processed Core

The list of any added material such as stabilizer, adhesive, and potting compound shall be given by a chain of `next_assembly_usage_occurrence` entities. The first `next_assembly_usage_occurrence` in the chain shall have the `product_definition` for the processed core as the `relating_product_definition`; the `product_definition` for the ply where the first added material in the list is applied shall be the `related_product_definition`. The successive `next_assembly_usage_occurrences` in the chain shall likewise link the `product_definitions` for the plies where subsequent added material in the list are applied.

If the processed core is made from one or more processed cores, then the `product_definitions` for the latter shall be related to that for the former by a set of `next_assembly_usage_occurrence` entities.

A processed core has a `representation` to denote its cell orientation, i.e., the ribbon direction for the core. A `representation_relationship_with_transformation` shall link this `representation` to the `representation` for the reinforcement orientation basis of the corresponding laminate table. The orientation angle is derived in the manner described for a ply - see Section 2.1.1.2.1 for details.

The shape of a processed core may be represented by an `advanced_boundary_shape_representation`, `faceted_boundary_shape_representation`, `geometrically_bounded_surface_shape_representation` or a `beveled_sheet_representation`. A `beveled_sheet_representation` is a subtype of `shape_representation` whose base boundary surface is based on a `composite_sheet_representation`. Two `measure_representation_items` characterize a `beveled_sheet_representation`. The first `measure_representation_item` in its set of `items` is a `plane_angle_measure_with_unit` representing the angle between the surface normal of the base surface to the beveled surface. The second is a `length_measure_with_unit` representing the height of the core measured vertically from the base surface.

2.1.1.2.3 Filament Laminate

A filament laminate product is associated with a `product_related_product_category` with a `name` of 'filament_laminate' (Figure 17). The filament laminate `product_definition` is related by a `make_from_usage_option` entity to its filament assembly `product_definition`, which will be associated with a `product` in a `product_related_product_category` with a name of 'filament_assembly'.

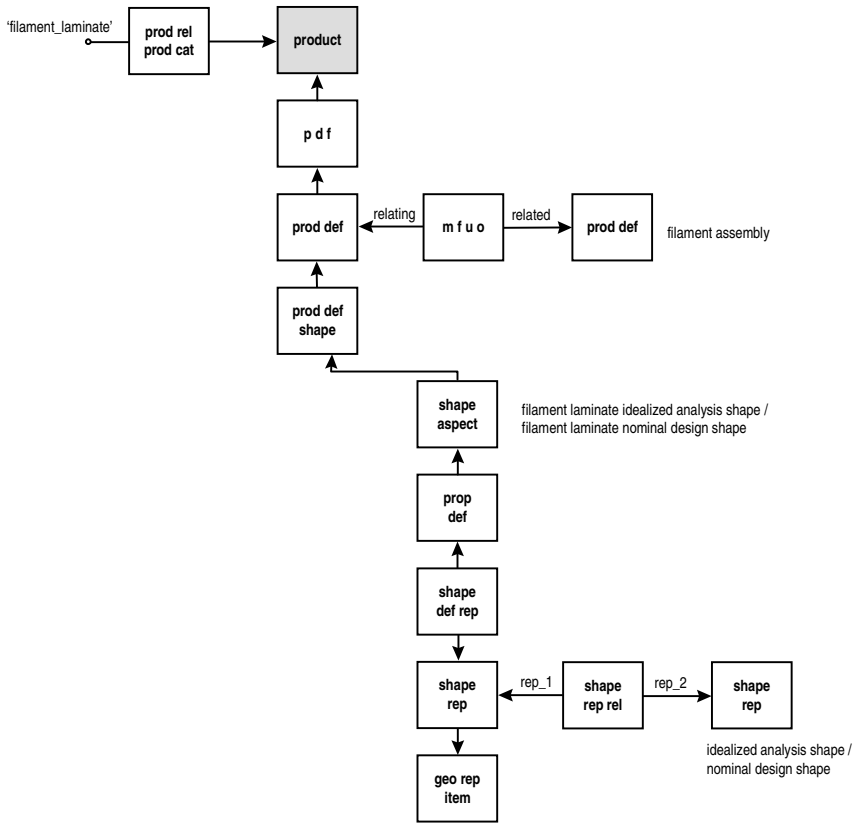


Figure 17: Filament Laminate

The shape of a filament laminate is given by a `shape_representation` for its cross section. This `shape_representation` is related to the nominal design or idealized analysis `shape_representation` through a `shape_representation_relationship`. The `name` of the `shape_aspect` is set accordingly to 'filament_laminate_nominal_design_shape' or 'filament_laminate_idealized_analysis_shape'.

2.1.1.2.4 Ply Laminate

A ply laminate product is associated with a `product_related_product_category` with a name of 'ply_laminate' (Figure 18). The ply laminate `product_definition` is related by a `make_from_usage_option` to the `product_definition` for the ply laminate table that is represented by a `ply_laminate_table` (see Section 2.1.1.1.1).

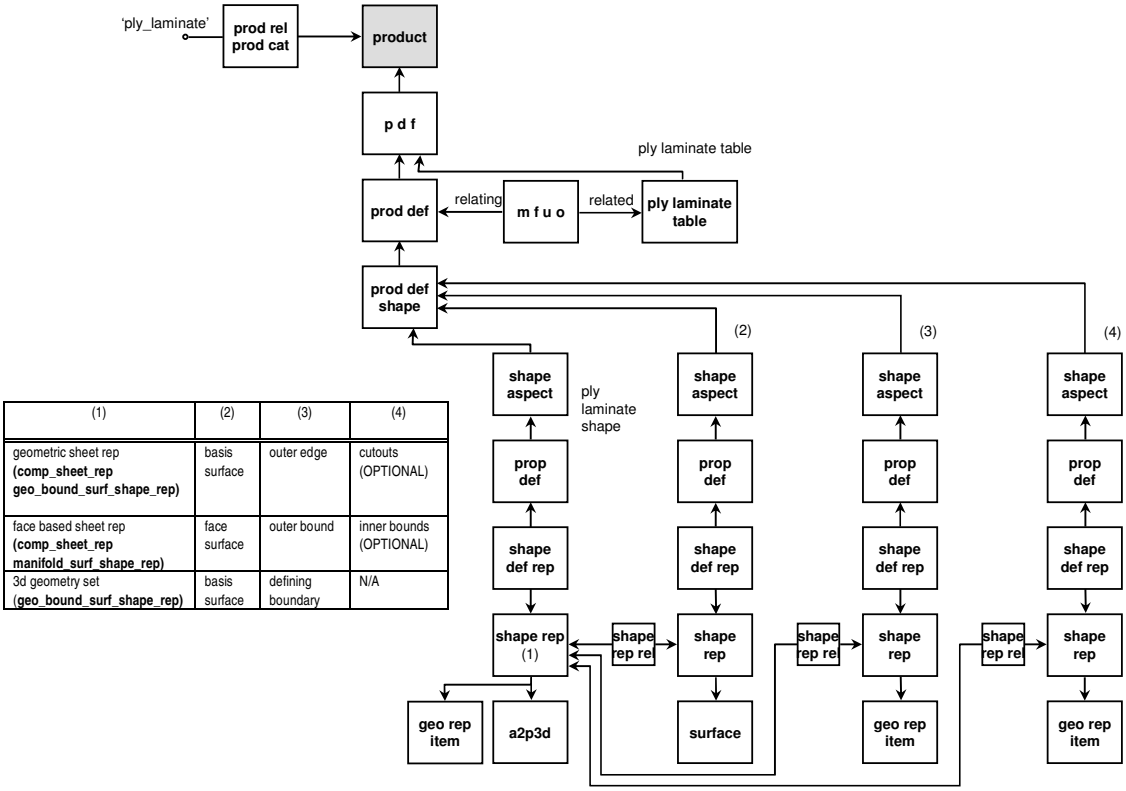


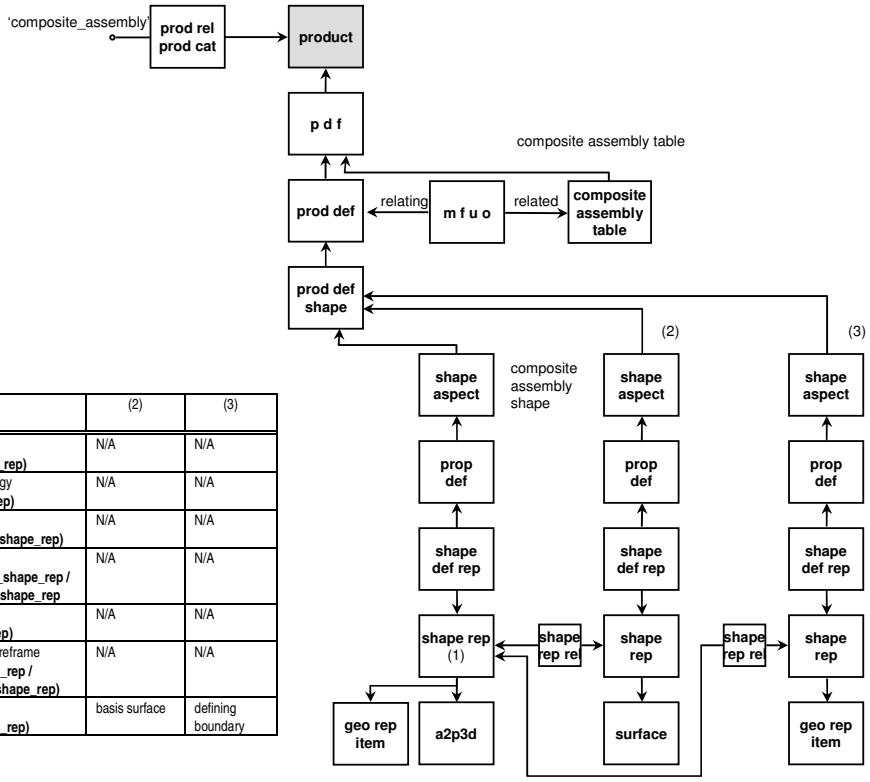
Figure 18: Ply Laminate

The shape of a ply laminate may be represented by a `composite_sheet_representation` or a 3D geometry set. The `composite_sheet_representation` shall be a `geometrically_bounded_surface_shape_representation` or a `manifold_surface_shape_representation`. Associated with the `composite_sheet_representation` are `shape_representations` for the basis or face surface of the ply laminate, outer edge or bound of the ply laminate, and optionally the cutouts or inner bounds for the ply laminate (see Section 2.1.1.2.1.1 for the respective `shape_aspect.name` values). Each of these `shape_representations` is related to the ply laminate `shape_representation` by a `shape_representation_relationship`.

A 3D geometry set shape is represented by a `geometrically_bounded_surface_shape_representation` entity. Associated with this `shape_representation` are `shape_representations` for the basis surface of the ply laminate (`shape_aspect.name` of 'basis_surface') and the defining boundary of the ply laminate (`shape_aspect.name` of 'defining_boundary'). The context of the basis surface is indicated by setting the description attribute of the corresponding `shape_aspect` to 'layup_surface', 'outer_mold_line', or 'inner_mold_line'.

2.1.1.2.5 Composite Assembly

A composite assembly product is associated with a `product_related_product_category` with a name of 'composite_assembly' (Figure 19). The composite assembly `product_definition` is related by a `make_from_usage_option` to the `product_definition` for the composite assembly table, represented by a `composite_assembly_table` (see Section 2.1.1.1.2).



(1)	(2)	(3)
advanced bndy rep **(advanced_bndy_shape_rep)**	N/A	N/A
manifold surface w/ topology **(manifold_surf_shape_rep)**	N/A	N/A
wireframe w/ topology **(geo_bound_wireframe_shape_rep)**	N/A	N/A
wireframe w/ topology **(shell_based_wireframe_shape_rep / edge_based_wireframe_shape_rep**	N/A	N/A
faceted bndy rep **(facated_bndy_shape_rep)**	N/A	N/A
nontopological surf and wireframe **(geo_bound_surf_shape_rep / geo_bound_wireframe_shape_rep)**	N/A	N/A
3d geometry set **(geo_bound_surf_shape_rep)**	basis surface	defining boundary

Figure 19: Composite Assembly

The shape of a composite assembly may be represented by one of the following shape representations: advanced or faceted boundary representation (`advanced_boundary_shape_representation` or `faceted_boundary_shape_representation`); manifold surface with topology (`manifold_surface_shape_representation`); wireframe with topology (`shell_based_wireframe_shape_representation` or `edge_based_wireframe_shape_representation`); nontopological surface and wireframe (`geometrically_bounded_surface_shape_representation` or `geometrically_bounded_wireframe_shape_representation`); or a 3D geometry set (`geometrically_bounded_surface_shape_representation`).

2.1.2 Materials and Properties

Stock material is treated as a product in AP 203 and AP 209. A stock material product shall be among the `products` of a `product_related_product_category` with a name of : 'isotropic_material', 'anisotropic_material', 'filament_assembly', 'discontinuous_fiber_assembly', 'braided_assembly', 'woven_assembly', or 'stock_core' (Figure 20). The stock_material `product_definition` may have an `approval` in AP 203 and AP 209.

Material properties, including finite element analysis material properties, are represented by the `property_definition` subtype `material_property`. The name attribute inherited from the `property_definition` supertype is used to denote the particular property being qualified or quantified. The `material_property_representation` entity links a `material_property` to a `representation` that may contain a `measure_representation_item` in its set of `items` to provide a quantitative value the property.

For a finite element analysis (FEA), the `material_property_representation` subtype `fea_material_property_representation` entity is used to link an FEA `material_property` to a property `representation`. There shall be a single FEA material property representation item for each material property. Therefore, the FEA material property `representation`

shall contain only one `fea_material_property_representation_item` subtype in its set of `items`. The subtypes of `fea_material_property_representation_item` represent finite element analysis properties such as linear elasticity, mass density, shell shear stiffness, and coefficient of thermal expansion. The material id assigned to a material by an application is represented by the name attribute of the representation. The material id shall be unique within the `fea_model`.

Conditions such as temperature and moisture content that relate to the material properties are grouped in a `data_environment` that is referenced by the `material_property_representation` entities as their `dependent_environment`. The `representation` for each condition is associated with the stock material through a `property_definition`. The `representation` of a material reference direction is likewise associated with the stock material through a `property_definition`.

2.1.2.1 Material Specifications

Material specifications that are applicable to a stock material are related to the stock material `product_definition` through an `applied_document_reference` entity. The stock material `product_definition` is contained in the items of the `applied_document_reference`. The `assigned_document` attribute inherited from the `document_reference` supertype of `applied_document_reference` points to the specification `document` (Figure 20).

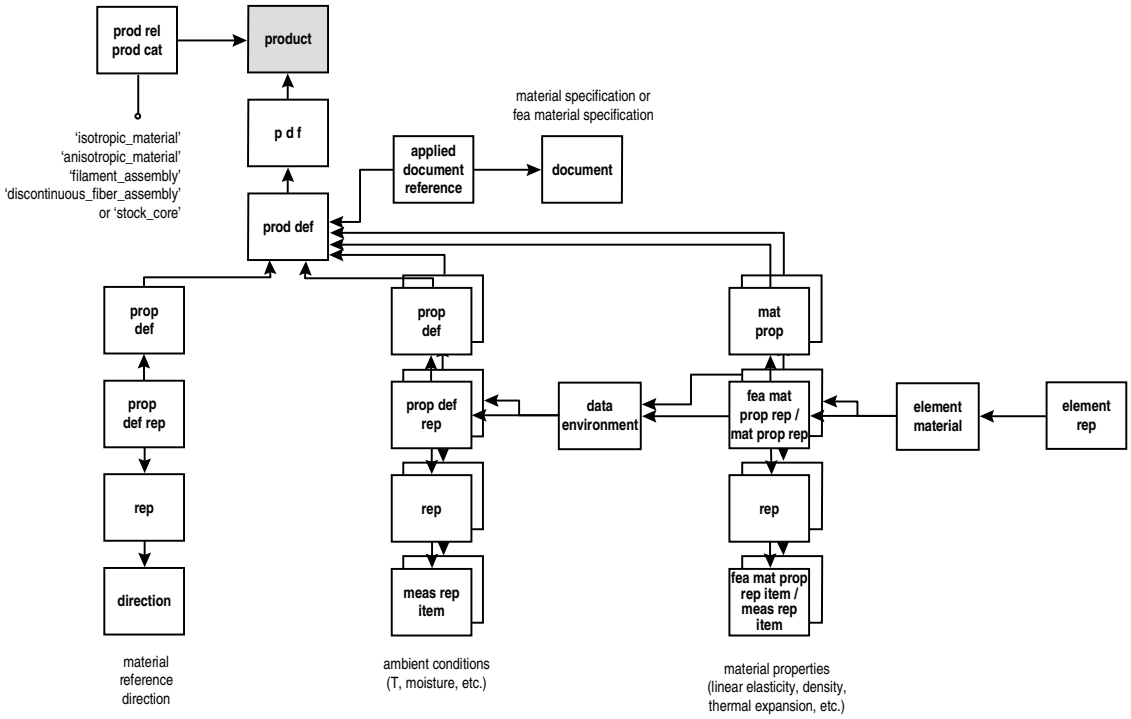


Figure 20: Stock Material

2.1.2.2 Material Callout

The designation of the material for a part is accomplished through a `make_from_usage_option` entity. The `make_from_usage_option.relating_product_definition` shall be the 'design discipline' `product_definition` for the part. If the component part or the composite constituent is produced from a single material, then the `make_from_usage_option.related_product_definition` shall be the `product_definition` for the material (such as an 'isotropic material', 'anisotropic material', or 'filament assembly'). If the component part is a composite, the `make_from_usage_option.related_product_definition` shall be the `product_`-

`definition` for the laminate table representation (e.g., `ply_laminate_table`, `composite_assembly_table`, or `thickness_laminate_table`).

3 Geometric Founding of Composite Constituent Product Definitions

The simplest case for composite constituent product definitions is when all product definitions use the same `representation_context`. No transformations are required for the simplest case. This applies to a Laminate Table subtype and to any Ply or Composite Constituent shape representations.

This is by far the most frequently instantiated case.

3.1 Referenced Shape in an Assembly with Additional Laminate Table Representation

Figure 21 represents the case where the laminate table subtype is founded with respect to the component/detail within an assembly. Note that it is not required for the component/detail be in an assembly, and that the laminate table subtype could also be related to the assembly.

This is the second most frequently instantiated case.

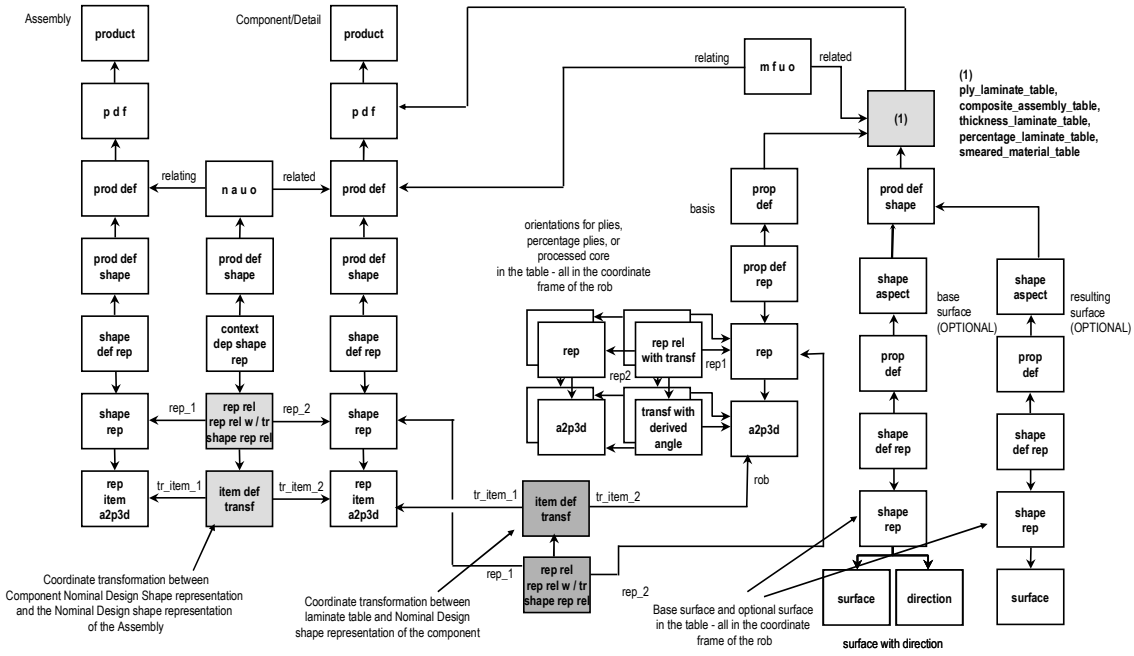


Figure 21: Referenced Shape in an Assembly with Additional Laminate Table Representation - Most General Geometric Founding Case

3.2 Founding of Ply Subtypes and Composite Constituents with Respect to a Laminate Table subtype – the Most General Case

The Ply shape subtypes and Composite Constituent shapes listed in Table 1 represent the different types of shape indicated on the right – hand side of Figure 22. Any of these shapes may be founded with respect to each other, or with respect to the Laminate Table subtype that they are a member of.

This is a rarely instantiated case included for completeness.

Laid Ply Shape
Flat Pattern Ply Shape
Projected Ply Shape – Surface Ply Shape
Projected Ply Shape – View Ply Shape
Processed Core Shape
Filament Laminate Shape
Ply Laminate Shape
Composite Assembly Shape

Table 1: Ply Subtypes and Composite Constituents

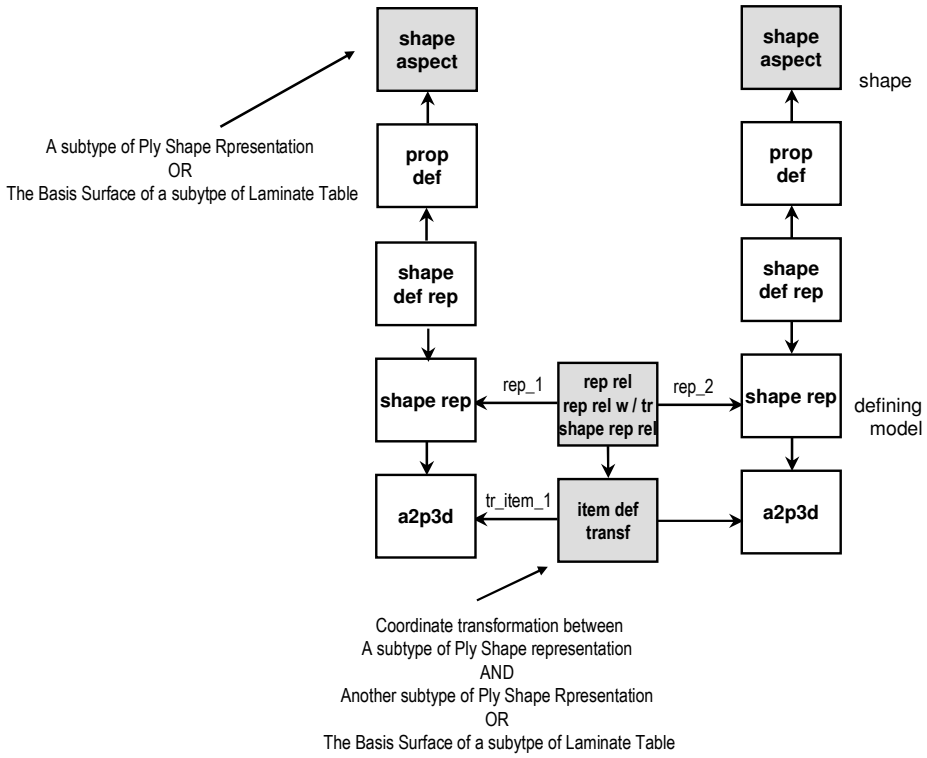


Figure 22: Founding of Ply and Composite Constituent Shapes - Most General Case

Annex A Availability of implementation schemas

A.1 AP203 2nd Edition

The long form EXPRESS schema for the second edition of AP203, which includes the definition of composite materials, can be retrieved from:

http://www.cax-if.org/documents/AP203E2_November_2008.exp