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## Appendix E

### EXPRESS-2 Rib Entities

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This appendix lists the 32 custom EXPRESS entity types that were developed for modeling the composite rib in Chapter 7. According to the EXPRESS language rules, the names and types of the sub-members of each entity are listed between ‘ENTITY’ and ‘END\_ENTITY’ statements. Comments are included after some of the members to better explain their functionality.

```
ENTITY rib;  
  c : REAL;          -- c and h_on_c are set by the poly_loop that defines the profile  
  h_on_c : REAL;    -- & they are included in rib for convenience during geometry building  
  profile : POLY_LOOP;  
  loads : rib_load_set;  
  features : rib_feature_set;  
  laminate : laminate_type;  
  geometry : FACE;  
  cost_model : process_model;  
  fea_model : ansys_model;  
  report : BAG OF STRING;  -- these could be combined into one text file  
END_ENTITY;
```

```
ENTITY rib_load_set;  
  fuel_burst_load : REAL;  -- N/m  
  max_shear_load : REAL;  -- N/m  
  brazier : REAL;        -- N/m  
END_ENTITY;
```

```
ENTITY rib_feature_set;  
  mouse_holes : BAG OF UNIQUE mouse_hole;  
  system_holes : BAG OF UNIQUE system_hole;  
  swages : BAG OF UNIQUE swage;  
  mouse_cleats : BAG OF UNIQUE mouse_cleat;  
  gang_cleats : BAG OF UNIQUE gang_cleat;  
  flanges : BAG OF UNIQUE flange;  
END_ENTITY;
```

```
ENTITY mouse_hole;  
  x_on_c : REAL;  
  top : BOOLEAN;  
  depth_on_c : REAL;  
  width_on_c : REAL;  
  cutter : POLY_LOOP;  -- gets assigned during the build process  
END_ENTITY;
```

```

ENTITY system_hole;
  x_on_c : REAL;
  y_on_c : REAL;
  radius_on_c : REAL;
  cutter : POLY_LOOP; -- gets assigned during the build process
END_ENTITY;

```

```

ENTITY swage;
  base_poly : POLY_LOOP;
  h_on_c : REAL;
  d_on_c : REAL;
  top_face : FACE;
  sides : BAG OF UNIQUE FACE;
END_ENTITY;

```

```

ENTITY mouse_cleat;
  at_mouse_hole : mouse_hole;
  a : REAL;
  b : REAL;
  w : REAL;
  web : FACE;
  flange1 : FACE;
  flange2 : FACE;
  to_rib_fasteners : BAG OF UNIQUE fastener;
  to_wing_fasteners : BAG OF UNIQUE fastener;
END_ENTITY;

```

```

ENTITY gang_cleat;
  x1_on_c : REAL;
  x2_on_c : REAL;
  pitch_on_c : REAL; -- determines how close the fasteners get placed
  top : BOOLEAN;
  a : REAL;
  w : REAL;
  web : FACE;
  flanges : BAG OF UNIQUE FACE;
  to_rib_fasteners : BAG OF UNIQUE fastener;
  to_wing_fasteners : BAG OF UNIQUE fastener;
END_ENTITY;

```

```

ENTITY fastener;
  type : fastener_type;
  loc_x : REAL;
  loc_y : REAL;
  loc_z : REAL;
  Fx : REAL; -- the +/- convention for the loads is:
  Fy : REAL; -- "The force is that which is exerted on the most directly referencing object"
  Fz : REAL; -- eg. If the fastener is referenced by a cleat, F is the force of the bolt on
that cleat
  geom : BAG OF UNIQUE face;
END_ENTITY;

```

```

ENTITY fastener_type;
  name : STRING;
  dia : REAL; -- mm
  tensile_lim : REAL; -- kN
  shear_lim : REAL; -- kN
END_ENTITY;

```

```

ENTITY flange;
x1_on_c : REAL;
x2_on_c : REAL;
top : BOOLEAN;
a : REAL;          -- spacing beside mouse_holes
w : REAL;
flanges : BAG OF UNIQUE face;
END_ENTITY;

-- this entity stores data about the manufacturing processes
ENTITY process_model;
name : STRING;
details : STRING;
knowledge : manufacturing_knowledge_base; -- manufacturing options
part_properties : panel_summary;          -- PCAD parameters
start_switches : BAG OF UNIQUE switch;    -- controls the process stages
stages : BAG OF UNIQUE stage;            -- generated from the above 3 entities
report : BAG OF STRING;
END_ENTITY;

-- This stores all the information about the part that is needed to link with the PCAD model
ENTITY panel_summary;
plys : BAG OF ply;
perimeter : REAL;
area : REAL;
END_ENTITY;

ENTITY laminate_type;
name : STRING;
plys : BAG OF ply;
quasi_E : REAL; -- N/(mm^2)
quasi_D : REAL; -- N/mm
END_ENTITY;

ENTITY ply;
fabric : fabric_type;
thickness : REAL;
orientation : REAL; -- angle in degrees
END_ENTITY;

ENTITY fabric_type;
name : STRING;
E11 : REAL; -- MPa
E22 : REAL; -- MPa
myu : REAL;
strn_xx_ult : REAL;
strn_yy_ult : REAL;
strn_xy_ult : REAL;
END_ENTITY;

-- Used to control the process steps for a particular design
ENTITY switch;
name : STRING;
and_switches : BAG OF UNIQUE switch;
or_switches : BAG OF UNIQUE switch;
not_switches : BAG OF UNIQUE switch;
active : LOGICAL; -- indicates if this switch is active in its process model
END_ENTITY;

```

```

-- Represents a separate stage in the current manufacturing model
ENTITY stage;
  name : STRING;    -- will become: process_model.name + stage_type.name
  type : stage_type; -- this is a reference to the object that stores the knowledge about this
stage
  processes : BAG OF process;
  time : REAL;
END_ENTITY;

-- Each object of this entity represents a separate process in the current manufacturing model
ENTITY process;
  name : STRING;    -- becomes: stage.name + PCAD_process.name
  type : PCAD_process; -- this is a reference to the object that stores the knowledge about
this process
  time : REAL;
END_ENTITY;

-- The inclusion of a particular stage in a design depends on the contents of the switches
bag of the active process model
ENTITY stage_type;
  name : STRING;
  details : STRING;
  steps : BAG OF PCAD_process; -- defines the individual PCAD processes
  and_switches : BAG OF switch; -- all of these switches must exist
  or_switches : BAG OF switch; -- at least one of these switches must exist
  not_switches : BAG OF switch; -- none of these may exist
END_ENTITY;

-- This is designed to be applicable to different composite part types
ENTITY manufacturing_knowledge_base;
  stage_types : BAG OF UNIQUE stage_type;
  all_switches : BAG OF UNIQUE switch;
  completion_switch : switch; -- must be TRUE for a valid design
END_ENTITY;

ENTITY PCAD_data_set;
  all_processes : BAG OF PCAD_process;
END_ENTITY;

ENTITY PCAD_process;
  id : INTEGER;
  description : STRING;
  details : STRING;
  parameters : process_parameter_group;
END_ENTITY;

ENTITY process_parameter_group;
  cost_eqn_id : INTEGER;
  setup_time : REAL;
  delay_time : REAL;
  min_crew : INTEGER;
  baseline_crew : INTEGER;
  max_crew : INTEGER;
  drivers : BAG [0,3] OF UNIQUE PCAD_cost_driver;
END_ENTITY;

ENTITY PCAD_cost_driver;
  type : STRING;
  Vo : REAL;
  Tau : REAL;

```

```

END_ENTITY;

ENTITY ansys_model;
  kps : BAG OF UNIQUE point;
  lines : BAG OF UNIQUE ansys_line;
  areas : BAG OF UNIQUE ansys_area;
  connectors : BAG OF UNIQUE point_pair;  -- used to model areas connected by
mechanical fasteners
  point_loads : BAG OF UNIQUE point_load;
  area_loads : BAG OF UNIQUE area_load;
  point_constraints : BAG OF UNIQUE point_constraint;
  reserve_factor : REAL;  -- considers all appropriate failure modes
END_ENTITY;

ENTITY ansys_line;
  kp1 : point;
  kp2 : point;
END_ENTITY;

ENTITY ansys_area;
  lines : BAG OF UNIQUE ansys_line;
  laminate : laminata_type;
END_ENTITY;

ENTITY point_pair;
  p1 : point;
  p2 : point;
END_ENTITY;

ENTITY point_load;
  at : POINT;
  Fx : REAL;
  Fy : REAL;
  Fz : REAL;
  graphic : BAG OF POLY_LOOP;
END_ENTITY;

ENTITY area_load;
  at : ansys_area;
  stress_x : REAL;
  stress_y : REAL;
  stress_z : REAL;
  graphic : BAG OF POLY_LOOP;
END_ENTITY;

ENTITY point_constraint;
  at : POINT;
  x_free : BOOLEAN;
  y_free : BOOLEAN;
  z_free : BOOLEAN;
  graphic : BAG OF POLY_LOOP;
END_ENTITY;

```