SUMMARY

This demonstration illustrates functionality specifically designed for the design and manufacturing of cloth/ply composite parts. The functionality allows users to develop mold line geometry, define cloth ply layups, generate 3D solid models of the composite parts and generate a variety deliverables including bill of material and flat pattern drawings.

COMPOSITE SCRIPT

INTRODUCTION

Welcome to our demonstration of Pro/ENGINEER's Pro/COMPOSITE module. For the next 20 minutes I would like to show you some of the features and deliverables which make Pro/COMPOSITE functionality unique. Pro/COMPOSITE provides the composite design engineer with a full set of tools for designing cloth ply lay up composite panels, similar to the one you see on the screen now. Once the design engineer has created his ply lay ups using features like core, ply, and preform, he can get a full set of deliverables from the model, including bill of materials, mass properties, and flat patterned drawings for each of the plys.

RETRIEVE PANEL_F PART

For this demonstration I would like to take you through the creation of this panel and then show all of the different deliverables which are available with Pro/COMPOSITE and Pro/ENGINEER. The basic panel shape is a blend. The green region is a stiffening bead (hollow on the underside). The brown regions are shapes to accommodate fasteners. The blue region is a stiffening core. The purple shows the boundaries of the various plys.

As we go through this demonstration, I think you will see that PTC's goal is to provide a complete suite of functions that integrate the design and manufacturing engineers' input into a single parametric, associative database. Given that database, then, we provide a complete set of deliverables for the design, manufacturing and fabrication processes.

RETRIEVE INTRO.LAY LAYOUT

The basic inputs to the composite design model come from two sources. First, the design engineers create mold line geometry and specify ply boundaries. Then, they use composite features such as plys, cores, and preforms to create 3D solid model representations of the composite panel. After that, manufacturing engineers can reference the panel to specify trim and stretch allowances, define mold geometry, and generate other fabrication tools.

Once these steps have been completed, a full set of deliverables will be available for the design, manufacturing, and fabrication engineers. For design engineers, of course, we will provide 3D solid model representations of the panel geometry. Then, using additional Pro/ENGINEER capabilities, like Pro/DETAIL, the design engineer will be able to create detailed drawings of these panels. Also, engineering analysis and mass property information will be available. For manufacturing engineers, Pro/COMPOSITE functionality will provide flat patterns for the individual plys, 3D core geometry and NC data for cores, and 3D geometry and NC data for the molds required to build the panel. Finally, for the fabrication engineers, we will provide ply charts, or bill of materials, for each composite panel and sequence drawings which show the steps required to lay up the composite panel.

RETRIEVE REF_SURF.PRT PART

Now let's create our composite panel. The design process typically begins with the air frame designer who creates (and owns) the geometry of the external aircraft surface. The composite design engineer, then, simply references this aircraft surface. Of course, because of Pro/ENGINEER's associativity, any changes made to the reference surface will be passed down to the composite part.

RETRIEVE PANEL.PRT COMPOSITE

Here I have begun the composite panel and I would like to step you through the preliminary steps to get to this point. I'm going to do this using our regen info capability which will simply step me through my model one feature at a time. Again, the first step is to give the name of a reference part or surface and have the geometry of that surface copied into my composite panel. Here we see that surface.

Once I have determined that my panel is going to be created as a composite part, I may, as composite designer engineer, want to add additional geometry. Here I'm creating stiffening beads on the panel surface. This is done using the same surface modeling capabilities that are available with Pro/ENGINEER's Pro/SURFACE module.

Next we're creating the geometry for the lugs. The surfaces are revolved and patterned to create two instances. Then each one is quilted into the main panel surface and filleted. At this point the geometry of my surface model corresponds to the OML, or outer mold line, of my composite panel. That is, this is the surface my mold will have when I start laying up plys.

The next step is to define where the ply boundaries will be. This is done using the usual datum curve creation techniques. Here a curve has been projected onto the outer mold line quilt. Another curve has been wrapped onto the surface. The first technique is useful when the designer knows what the resulting geometry should look like in the formed state. The second technique is useful when the designer knows what the flat pattern of the ply will look like and wants the system to determine what the resulting formed geometry will be. A third boundary will be used to place the core feature. Notice that Pro/ENGINEER allows us to create either open or closed section boundaries.

The next step is to define one or more coordinate systems for specifying ply orientation. I do this using any of the normal coordinate system creation techniques. Here I have created one coordinate system on my panel to specify ply orientation. The second coordinate system was imported along with the reference surface and might correspond to aircraft zero.

The next step is to define a library of materials that I can use for my lay ups. Here I will create a new composite material by giving it a name and specifying the desired parameters. The parameters in this file include the density and the thickness of the material. I can also specify whether the material has a specific fiber orientation or not. For example, a normal fiberglass ply would have fiber orientation associated with it. However, a thin sheet of adhesive used for securing a core might be anisotropic. In addition, I can specify joggle offsets to indicate how smoothly the material ramps up over other plys.

Now that I have defined my materials I can begin to create the ply features. I'll select the full body option, telling the system that I want to create the ply across the entire surface of my quilt. Because this is the first ply, the system prompts which direction I want to lay up from my outer mold line. Here I will place the plys above the surface. Next the system prompts me to select a material from my library. I've specified that this material has a direction associated with it, so the system prompts me for a coordinate system and orientation angle. Once that is done, the system creates the appropriate ply geometry. What you see here are two quilts, the original quilt, corresponding to the outer mold line, and now a new quilt, corresponding to the inner mold line. The offset between the two corresponds to the thickness of my full body ply.

Next I want to create a partial ply using the first boundary curve. Again, I'll go in and select the ply feature. Now I will select the boundary option. At this point, I simply select the curves to define the boundary of this ply. The system then asks which side to create the ply on. I'll create it on the left. Again I will select a material, coordinate system, and fiber orientation angle. In a few moments the new part will be drawn showing the updated inner mold line.

Next I want to create a partial ply which is offset from a curve. One of the principles of the Pro/COMPOSITE module is that a composite panel may have many, many plys, but a large number of these plys will all be related to the same boundary. We have built the functionality in such a way that the user does not have to create individual boundaries for each ply. For example, I have only created one boundary for my core feature, but I want to use it for two features. One is the underlying adhesive which will hold the core in place and which will be slightly larger then the core itself. Then, I will reuse that boundary for the actual core feature.

Here I will build the adhesive by selecting the ply feature and specifying the options offset and boundary. As before, the system prompts me to select the boundary. Next, I specify that the ply should be created inside the loop. I select the adhesive material, and since that material does not have any fiber orientation, I am not prompted for coordinate system or angle. Next, I am prompted for the offset, and I will create it to be 15 mm outside of the

boundary. If necessary, I could have even specified individual offsets for each side. And here is the resulting geometry. I see the new inner mold line updated to show the adhesive ply. I also see a dotted green boundary. This is a boundary which the system has created for me as an offset from the one I originally used. Now I can use that boundary for specifying additional plys or offsets.

As I said before, it is quite common to have many plys reference the same boundary, so I now want to show how we can create a pattern of offset, draping plys. I will select the pattern and offset options and pick my spline curve as the boundary I want to use. I will create the material to the right side of the boundary, and I will specify my material, coordinate system, and orientation angle. Next the system prompts me for the offset and the offset direction. I will offset 10 mm to the left. Here the system has created the first ply. Now, I can use the basic Pro/ENGINEER pattern capabilities to create additional plys. In this case, I'm going to select the offset parameter and tell the system that I want it to build additional plys so that each one will overlap the one below it by 10 mm. Also, as I add each ply, I would like it to rotate the orientation angle by 45 degrees. Finally, I will tell the system how many plys I want, and it will create the appropriate geometry. The resulting geometry shows how each ply overlaps the ply below. Pro/COMPOSITE automatically takes care of the joggle geometry as plys drape over lower plys.

Next I want to create a core feature. Here I will select the core feature from the composite feature menu. The rest will be very similar to creating a ply feature. I can specify whether I want my core to be offset from a boundary or not, and then I will select the appropriate boundary. Here I'm selecting the same boundary that I used for positioning the adhesive ply. By doing so, I'm sure that both the adhesive and the core features will update automatically whenever I make a change to the one boundary. The system prompts me for which direction I want to create the core in, and then it prompts me for the material. Core material files are very similar to ply material files in that they prompt me for an average density, a thickness, and a fiber direction associated with the core material. In addition, the system understands that the side surfaces of a core feature should be beveled, and it will now prompt me for an overall bevel angle, which I will make 45 degrees. In a moment, the system returns with the new inner mold line showing the bevel core geometry.

When I am done creating composite features, I can turn my two mold lines into a single solid part using the solidify feature. Here is the resulting composite panel. At this point I may want to create additional solid features like holes or cuts. I can do that just as with any other Pro/ENGINEER part.

I would like to point out that, for this demonstration, I have built my composite panel in a very ordered fashion. That is, first creating the quilt surfaces, then creating the ply boundaries, then creating the ply features. Of course, I can go back at any time and make changes, insertions, or deletions to any of those aspects of my composite panel. For example, even after I've solidified my composite part and created hole features in it, I can go back and add new ply boundaries, create new plys in the middle of the existing sequence, reorder plys, or even add additional surfaces to my outer mold line quilt. In all cases, the composite panel geometry would update appropriately.

SHOW DELIVERABLES

For the next part of my demonstration, I would like to show you some of the deliverables which I can generate from my composite panel. First and most obvious is the fact that I do have 3D solid geometry corresponding to the actual panel. Given that, it is easy to generate the mass properties for my panel. I'll do this in the same manner as with any solid part. It is important to note that Pro/ENGINEER recognizes this part as being made up of multiple composite materials, each with its own density, rather than one homogeneous material. As such, it will calculate the true mass properties of this composite part.

Another benefit is that I can generate cross sections on my panel. Here I will create a cross section going through axis A4 of my lug and parallel to the front surface of my part. What I see here is a composite cross section. All of the contiguous plys are delineated with one single boundary. Each core feature is also indicated with its own single boundary and is crosshatched. Of course, I can now display this cross section on a drawing.

The third deliverable from my model is the bill of materials. Here the system automatically generates a table which lists each ply, its material, its orientation angle, and the sequence that it appears in.

One request from our customers is to generate the geometry of the core features in their flattened state. This is useful because it allows them to create dimensioned drawings and NC tool paths to cut the core geometry. On Pro/ENGINEER, I can select the flat core option, then select any core on my composite panel. I will give that core and feature a name, and Pro/ENGINEER will automatically create a new part for me whose geometry corresponds to the geometry of the flattened core in this panel. Then, I can retrieve that part in a separate window. As I said before, I could place this part on a drawing and dimension it, or bring it into the manufacturing module and generate NC tool paths to cut the core geometry.

RETRIEVE PANEL.DRW DRAWING

The next deliverable is a standard, dimensioned drawing of the composite panel. Here I will retrieve a drawing that I've made of my panel. As with any other Pro/ENGINEER drawing you see that I can have multiple views of my model, and I can display all the feature dimensions. Here are all of the dimensions for the boundary features that I've created on my reference surface.

On sheet 2 of my drawing, I've created a special view for the composite panel. In this view, I've used our note capability to automatically display where all the boundaries are for each of the plys in the model. As I add new plys to my model, these notes will automatically update.

FLAT PATTERN DRAWINGS

The next deliverable is flat pattern drawings for individual plys. Pro/COMPOSITE allows the user to develop flat pattern drawings from any ply that is placed on a developable surface. For this demonstration, I have created geometry corresponding to one individual ply just to help demonstrate how plys are flattened. This ply has actually been created in sheet metal mode, so I can orient it to the front view and then use the unbend feature to generate the flat pattern. Of course, for a composite panel, there is no real need to create 3D solid geometry for each individual ply. Instead we allow the user to create flat pattern drawings directly in the drawing environment. Here is the flat pattern drawing of my ply. Notice that this drawing can be annotated with material name, fiber orientation, and mass property information related to that individual ply.

SEQUENCE DRAWINGS

Another deliverable from the composite model is the in-process sequence drawing that shows the composite panel at each stage during the fabrication process. As I showed you earlier in this demonstration, I have the ability to step through my part feature by feature. What we are showing here is similar to a multi-sheet drawing where we simply step the composite panel through each feature, one sheet at a time.

MAKE BIG CHANGE

I would like to conclude my demonstration by showing the associativity between our design model and all of the deliverables. To do that, I'm going to retrieve the reference surface I used to create the composite panel. As with all Pro/ENGINEER models, this is parametric and I can modify any of its dimensions. Here, I will change the conical surface on the right-hand side so that the rear edge is much larger then the front edge.

SHOW EACH DELIVERABLE UPDATE

Here is my composite panel. When I update it, you will see the new geometry is reflected. Notice that not only do all of the plys update, but that even the outline of my core feature has updated such that the right edge remains parallel to the edge of the reference surface. Here you can see the resultant composite panel.

Next let's look at the flat core part. We'll call that up in the small window and when I update the part, it too updates to reflect the change that I made to my reference surface.

Next I want to show the flat pattern update. Here is my model of the ply in the flattened state. Again, I will update to reflect the change. Here is the flat pattern drawing also updated. Finally, I can go to my sequence drawing and show that all the views there update too.

As you can see, Pro/ENGINEER's Pro/COMPOSITE module provides engineers with powerful tools that are well suited for composite design. The composite models are parametric, and, of course, they are fully associative with a full range of deliverables.
With this set of tools then, including Pro/ENGINEER, Pro/COMPOSITE, Pro/DETAIL, Pro/MANUFACTURING, and Pro/MOLDESIGN, we provide a complete suite of tools to integrate the design, manufacturing, and fabrication engineers' work into a single parametric, associative database.