

Autodesk®

Technical Surfacing

AliasStudio 2008



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AliasStudio 2008

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CONTENTS

Learning Technical Surfacing v

Introduction to Technical Surfacing Tutorials v

Introduction to the Tutorial 1

Some Common Modeling Basics 3

Quality Defines the Model 3

How Different Types of Input Affect the Model 4

Loading and Organizing Data 4

Interface Arrangement 7

Traditional Surface Modeling 9

Creating and Fitting Curves 11

Creating blends between the main curves 13

An explanation of Continuity types 14

Fitting Curves to X-scans 18

Fitting Curves to Z-scans 22

Surface Creation 25

Introduction to Patch Layouts 25

The Importance of Helper Surfaces 26

Understanding and Refining the Theoretical Model 27

Constructing the Main Surfaces 33

Extending the Theoretical Line 33

Constructing the Side Surface 34

Constructing the Top Surface 37

Applying a Transition Between the Front and Top Surfaces
43

Applying a Transition Between the Rear and Top Surfaces
49

Transition Surfaces 55

Constructing Simple Transitions 55

Constructing a Transition Surface at the Rear of the Model
61

Constructing Ball Corners 64

Finishing the Model 71

Advanced Surface Modeling 73

Handling Blend Curves 74

Crucial Blend Curve Tools 75

Information Provided by Blend Curves 76

Blend Curves as Transition Curves 79

Blend Curve Constraint to a Surface Edge 80

Blend Curve Constraint to an ISO parameter 81

Blend Curve Constraint to a Curve-On-Surface 81

Blend Curve Constraint to a Curve 82

Understanding the Align Tool 83

Handling the Align Tool 83

Basics of surface fillets	90
Selection Process	90
Undo All	94
Addressing Interior Breaks in Continuity	95
When to use Bezier Surfaces instead of NURBS Geometry	95
When to use NURBS Geometry instead of Bezier Geometry	97
Choosing the Right Curve for the Job	98
Surface Continuity	99
Model Check	100
Dynamic Section	101
Clipping Plane	102
Minimum Radii	103
CV Distribution	103
Span Distribution	104
Surface Evaluation	105
Index	109

LEARNING TECHNICAL SURFACING

Introduction to Technical Surfacing Tutorials

A general overview of the tutorials.

Autodesk AliasStudio provides a complete set of interactive surfacing, modification, and evaluation tools for creating surface models that meet the demanding levels of quality and precision required in manufacturing.

In this book, we will present examples of typical production workflows using AliasStudio. We will introduce powerful tools and interactive features available in SurfaceStudio and AutoStudio, and demonstrate how to use them to accomplish your surfacing tasks.

These tutorials are densely packed with information and techniques that may be new to you. You may want to re-read the lessons after completion, or even repeat the more difficult lessons.

Some techniques, especially those related to fitting curves and direct modeling, are interactive and can be challenging. You may want to practice these skills after completing the tutorials.

For more information

Note that these tutorials are introductions to technical surfacing solutions and workflows. They are not intended as an exhaustive guide to the capabilities and options of the AliasStudio tools. These tutorials are designed to work with SurfaceStudio, but will also work with AutoStudio and Studio with Advanced Modeling.

For additional information and more comprehensive explanations of tools and options, refer to the *Modeling in AliasStudio* section of the online documentation.

Learning objectives

- Background information about SurfaceStudio and the tutorials
- Determining your learning level
- Conventions used in these tutorials

Where to begin

Establish what learning level you are at before starting.

The first tutorial covers some material that may already be familiar to you. You can make decisions about these tutorials based on whether you are an absolute beginner or already familiar with Autodesk AliasStudio products.

> Absolute Beginners

You should start with the Learning AliasStudio tutorials at the very beginning of *Interface Basics* (page 125), work through all of the Modeling tutorials, and then move on to the Foundations of Surface Modeling tutorial.

> Users Familiar With Autodesk AliasStudio Products

However, you will still want to familiarize yourself with new or SurfaceStudio-specific features. Read What's New.

Graphic Conventions

Explains graphic conventions used in the tutorials

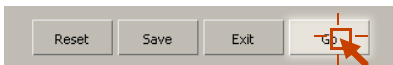
- To highlight part of a screen shot, we show it in a lighter shade.
For example, the following illustrates the location of the close box on a view window:



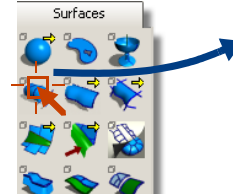
- To indicate a click or a double-click, we use these symbols:



For example, the following illustrates clicking the Go button:



- A blue arrow represents *dragging*.
For example, the following illustrates clicking and dragging a tool from a tool palette:



- In the beginning lessons, when we ask you to choose a tool, we show the tool's icon next to the instruction.



Terms

Explains terms used in the tutorials.

Click

Move the mouse pointer over an object and press a mouse button once.

Double-click

Move the mouse pointer over an object and press a mouse button twice fast.

Drag

Move the mouse pointer over an object and hold down a mouse button. Then move the mouse with the button held down.

The Scene

The 3D "world" inside the view windows.

The Model

The curves, surfaces, and points that make up the object you are creating.

INTRODUCTION TO THE TUTORIAL

All of the tools and features required to perform this tutorial are available in SurfaceStudio and AutoStudio, and may be available in Studio, depending on the options purchased.

This tutorial is intended for those users who want to learn surface modeling. In order to successfully complete this tutorial, we strongly recommend that you have a basic understanding of AliasStudio. The ideal student for this tutorial will have completed all of the AliasStudio basic tutorials, and have achieved, or have experience equal to, a Level 2 design status. SurfaceStudio should be used to accompany this tutorial.

Upon completion of this tutorial, you will have an understanding of the following methods

- How to create curves and surfaces
- How to match curves and surfaces
- How to evaluate the finished model.

While this tutorial offers a recommended step-by-step strategy for surface modeling, other tools and methods will be addressed to show alternative methods and their associated errors.

Given that there are a number of strategies that can be employed to surface a model, the successful completion of a surface modeling project ultimately depends on a number of factors.

Key factors that contribute to a successful surface modeling project

- The software utilized to carry out the project
- The desired quality of the finished product
- The time allocated for the project.

An iterative method will be employed in this tutorial to detail the basic steps involved in surface modeling; however, it must be stated that you may eventually find a methodology unique to your environment, or creative process, that works best for your requirements.

This section covers:

- Tutorial overview
- Prerequisites
- Introduction to surface modeling.

SOME COMMON MODELING BASICS

Quality Defines the Model

Surface models can be constructed to meet a number of quality levels that depend on the intended purpose of the model and the time allotted for the project. For instance, a model that has to be milled immediately as a 1:4 scaled model will have a different design phase than a model of a digitized master that is intended for a major CAD system (such as CATIA, or Unigraphics).

Surface modeling quality levels

- Class A quality (sometimes referred to as Class 1)
- Class B quality
- Class C quality

Often, quality levels have no fixed definitions as companies often institute their own standards that reflect the demands of their particular industries. Details that are important to surface quality may include the use, or negation of, construction tolerances, highlight standards, trimmed surfaces, radii shape, flange availability, Bezier surfaces, and triangle surfaces.

In general, a surface modeling project can be defined by three questions.

- 1 Do the construction tolerances of the continuity between surfaces match the construction tolerances for the required data of the next step (CAD system, milling)?
- 2 Do the quality of highlights and curvature combs meet the requirements defined by the designer responsible for the model?
- 3 Do the data requirements of an external package match those used to create the model?

When working with SurfaceStudio, you should begin by setting the construction tolerances. The input construction tolerance levels will depend on the type of system employed to execute the design. If you do not know the construction tolerances at the onset of your project, you can follow one simple rule.

Solid modeling systems (Pro/Engineer, SolidWorks) require small position construction tolerances. Ensure your construction tolerance values work with your solid modeling system.

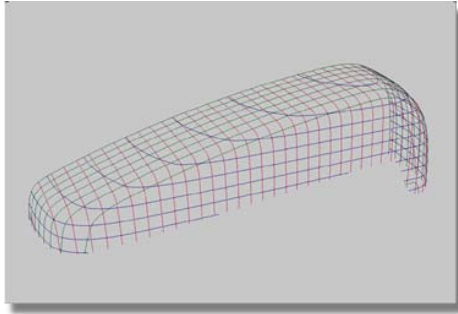
Learning Objectives

In this section you will learn how to:

- Set up the software to suit your working preferences
- The basic concepts of modeling.

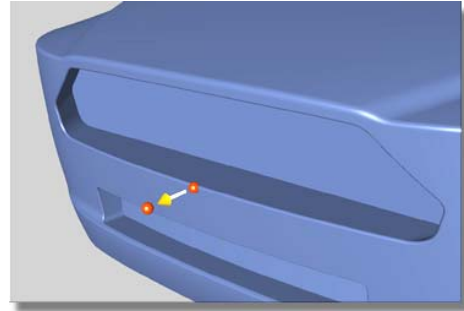
How Different Types of Input Affect the Model

Surfaces can be modeled from several input types. One of the more common methods of surfacing is to base the model on the input derived from a scanned model. Some model scanning techniques can produce point clouds while other scanning techniques produce curves instead of points. Depending on the technique employed during the scanning procedure, the data can be either be sorted or unsorted.

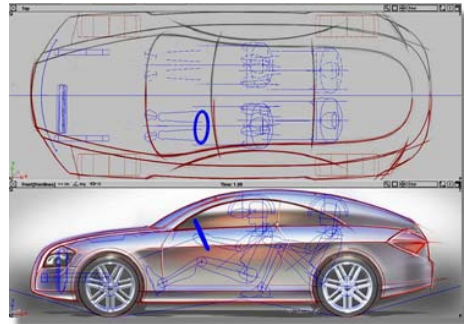


For the purposes of surface modeling it is better to have sorted data. If your scanning technique produced an unsorted point cloud instead of sorted section data similar to the image above, additional work is required to triangulate the points and cut the facets.

Another type of input is derived from a completed surface model that has yet to be modified. In these cases, surface data and hard points can be fitted with a new, updated model.



In other cases, input may consist of a collection of sketches and a package similar to the image below.



Regardless of the type of input data, surface modeling is largely an interpretation of a variety of inputs. For the modeler it is imperative to achieve an understanding of the design and the character of the model. With any surfaced model there are a number of intricate details that lay hidden below the surface, known only to the designer and modeler. Due to the precision of modeling software, the modeler must develop a close working relationship with the designer in order to surface the model. After all, surface modeling is a creative process that finishes a design.

Loading and Organizing Data

To work with saved data, you must first load it into AliasStudio. After you open the data you can organize it into layers, allowing you to manage it more efficiently.

In this lesson, we will show you how to work with SurfaceStudio files, open and organize files.

Opening the Lesson File

Begin by loading sample scan data from a disk. This will demonstrate how SurfaceStudio organizes files into projects. The sample scan data exists in the form of courseware files.

You will find these courseware files on the *AliasStudio Documentation CD* in the *CourseWare/wire* directory.

Organizing your files into projects and directories helps you manage your work efficiently. Keeping an organized file system ensures that you do not misplace important data, and makes the archiving process simpler.

File Organization

When you first set up your user account for use with SurfaceStudio, a directory is created in your home directory called *user_data*. By default, this is where SurfaceStudio stores files that you create.

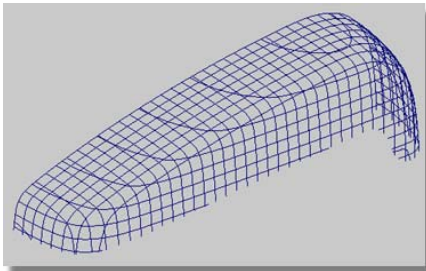
Inside the *user_data* directory you will find directories for *projects*. Project directories allow you to organize all the files associated with a job. Each project directory contains sub-directories for the different types of data, including wire files, cloud data, and pix format images.

The *wire* directory is used to store *wire files*. These are the files created when you save a model in SurfaceStudio. These files contain all the information about that model.

The initial set-up creates a project called *demo*. Until you create a new project, this is the default project.

The *user_data* directory may also contain a directory called *CourseWare*. This is where you will find the example files for use in these tutorials. If your *user_data* directory does not have a *CourseWare* sub-directory, you must copy it from the *AliasStudio Documentation CD*.

The sample file you will load contains scan data for a center console from an automotive interior.



Opening a Wire File

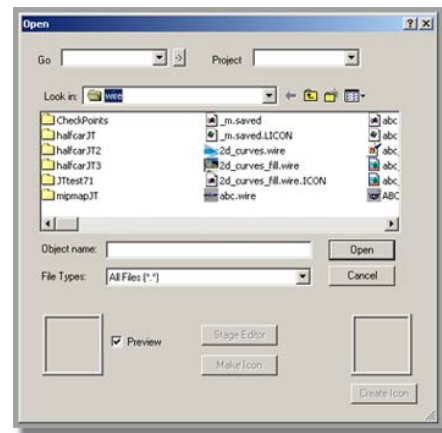
To use the **Open** command to load a model from disk

- 1 In the **File** menu, choose **Open**.
The file browser appears.



If **Type of File Browser** is set to *AliasStudio* in **Preferences > General Preferences** - □ (System section), your file browser will look different from the one displayed below.

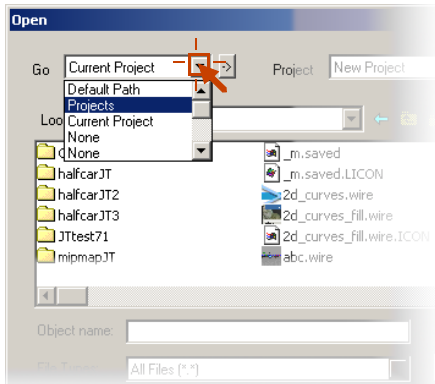
For step by step instructions on how to load your file using the *AliasStudio* browser, consult the *Introduction to 3D* (page 157) tutorial in *Learning AliasStudio*.



You are currently in the *wire* directory of the *demo* project directory. This is the default location for storing wire files until you set up a new project.

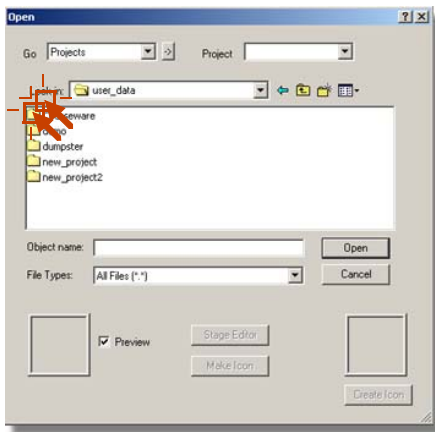
You need to navigate to the *CourseWare* directory to load the example wire file for this lesson.

- 2 Click the arrow to the right of the **Go** field and select **Projects** from the lister.

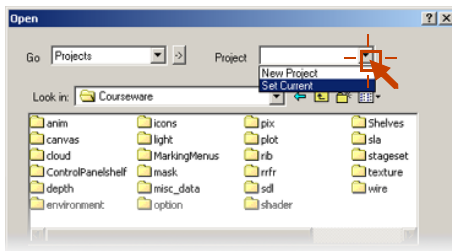


The list of project directories is displayed in the main browser window.

- 3 Double-click the Courseware directory in the browser window to display its content.



- 4 Click the arrow to the right of the **Project** field and select **Set Current** from the lister.



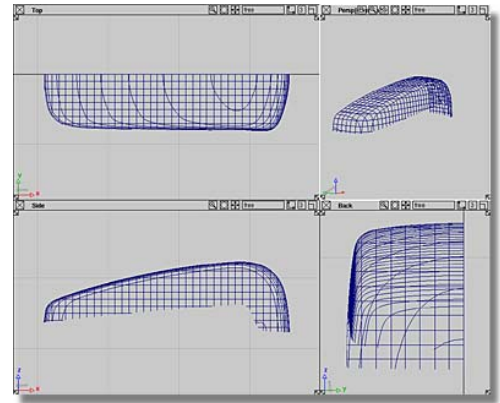
This changes the current project from demo to CourseWare. From now on, the file browser will show the content of the CourseWare directory by default when you open it.

- 5 In the browser, double-click the file called Lesson2.wire.

SurfaceStudio asks you if you want to delete everything in your model before loading the file.

- 6 Click **YES** to continue.

SurfaceStudio loads the file.



If you were to answer **NO** to this request, SurfaceStudio would keep any existing model information and load the new file into a new *stage*.

Stages are a method of organizing model data in different files. You will not use stages in this tutorial, but you can read more about them in the Basic Tools manual.

Interface Arrangement

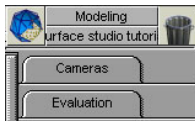
To arrange the SurfaceStudio interface

- 1 Load the shelf set named **SurfaceStudio Shelf**.



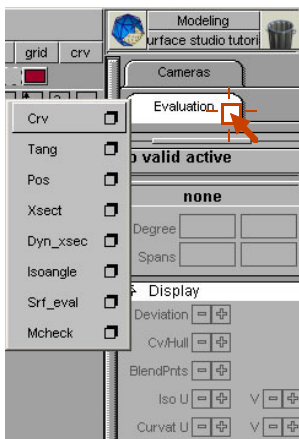
The **SurfaceStudio Shelf** is specifically designed for this tutorial. Some tools have been removed from the shelf to allow you to concentrate on those tools required for this tutorial.

- 2 Load the Control Panel shelf set named **SurfaceStudio Control Panel Shelf**.

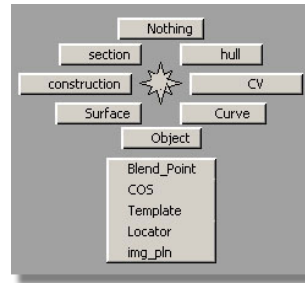


The Control Panel shelf provides you with a faster avenue to a customized collection of tools. It is a good habit to use a customized Control Panel shelf. As the Control Panel shelf does not offer enough space for all of the icons, use a different method to access the tools. Instead of recognizing icons, you must know the full names of the tools. (For example, the full name of the **Fillet** tool is **Surfaces > Surface fillet**).

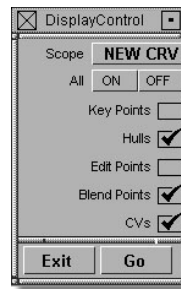
To access the tools, right mouse click on a given tab to produce a sub-menu pop-up window containing a list of tool names and option boxes (where applicable).



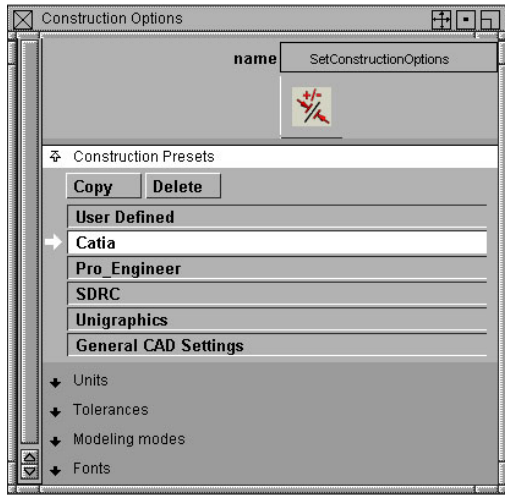
- 3 Load the marking menu named **SurfaceStudio Marking Menu**.



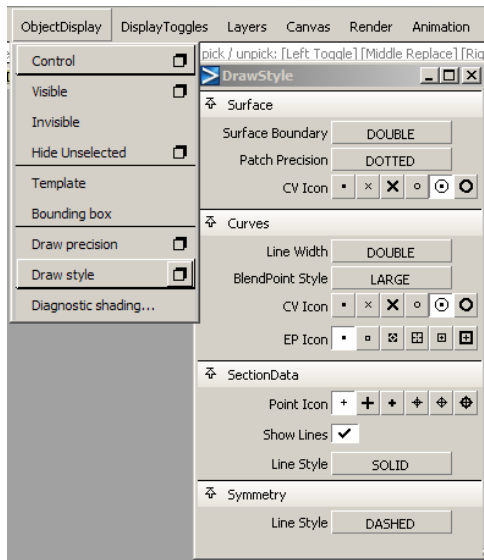
- 4 Set the **ObjectDisplay > Control** - panel as shown in the image below.



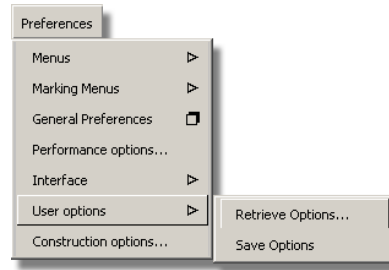
- 5 Choose the **Preferences > Construction options** and click the **Catia** option. The Construction Options window allows you to set a variety of modeling tolerances. If you will be exporting your data to one of the CAD packages listed in the **Construction Presets** tab, simply click the name of the CAD package and SurfaceStudio will automatically set the tolerances appropriate to that software.



- Open the **ObjectDisplay > Draw style** option box and set the style of curve and surface CVs as shown in the image below. For beginners, changing the draw style of CVs to these settings will allow for easier recognition.



- Save the selected options by choosing **Preferences > User options > Save options** from the menu.



- Restart the computer to make sure your options are saved.
- Open SurfaceStudio.

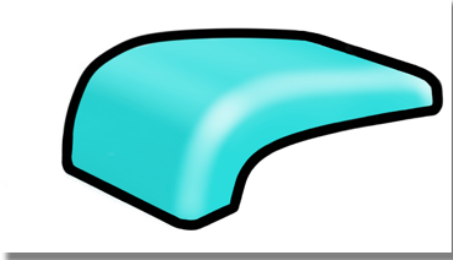


In this tutorial, the modeling process will be conducted solely in the Perspective view. You will be asked to change views in order to facilitate the best possible view of the model. For each instance when you are asked to change views, always use the **Viewing Panel** located in the Perspective window.

Traditional Surface Modeling

The first step is always the hardest. So, you had better not start with the software. Instead, turn away from your screen and take a little side-trip to a workshop.

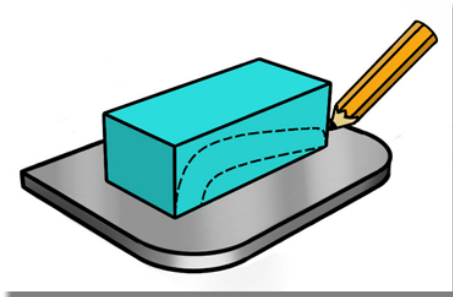
Inside the workshop, there sits on a workbench a foam cube that you will transform by hand into a model resembling the one below.



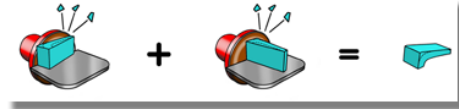
Later in the tutorial, you will recreate and surface the model using SurfaceStudio. Before you begin though, take a moment to imagine what steps you will undertake in building the model. This exercise will provide you with a guide for detailing the construction steps.

What should you do first?

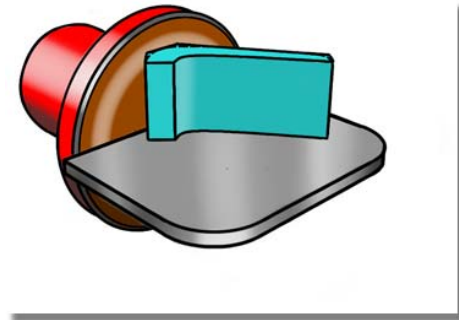
You can start by using a pencil to sketch the center line onto the side of the cube body.



Once you have sketched your design onto the foam body, go to the grinding machine in the corner of the workshop and sand your foam block. You will find it quite difficult to sand the entire center line in one step. Instead, try sanding the middle portion first. After that, the front and the rear can be worked independently.



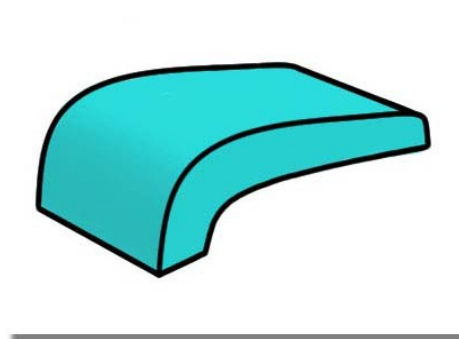
You will finish with the transitions between front/top and rear/top.



The bottom is easy. You will do it in a similar fashion to the top but using a different tool.

Now, sketch the top view onto your foam block and return to the grinding machine to perform the same procedure as before.

Having fashioned a model from the foam cube, you are left with a theoretical model – a model with no fillets.



To complete the model, shape the fillets and ball the corners by hand.

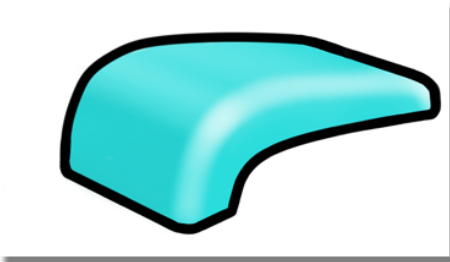
Begin the fillets by defining the fillet lines with tape.



Following the taping procedure, sand the foam by hand until you have produced the fillets and rounded corners.



Continue to refine the model until the end product resembles the model below.



Congratulations, you have produced a foam model using a method that is tried, tested, and true. As we step further into the tutorial, you will use this same classic method to develop your surface model.

CREATING AND FITTING CURVES

After you have fashioned your model from the foam cube, scan the model's surface to produce a series of scan lines that represent your creation. If the scan lines do not look exactly the same as the foam model, keep in mind that the model was handcrafted, and as a result, small surface degradations may have been created during the model's construction. It is also entirely possible that the scanning device made errors due to a discrepancy in stated construction tolerances. Regardless of the cause of the errors, it should be understood that the primary role of the scan lines is to provide a guide for the dynamics of the model. Before beginning the surface modeling, use the scan lines to garner information about the model.

Similar to sketching on the foam cube, the first step in the surface modeling process is to create a center line based on the scanned input.

To view all of the scan lines

- 1 Open the wire file `Curve Fitting.wire`.
- 2 Pick all of the scan lines.
- 3 Choose the **View > Look at** tool.



The scan lines used in the tutorial are degree 1 curves. When using the **Pick > Component** tool, the scan lines can only be selected as curves, not sections.

With all of the scan lines displayed, you might find that the model is cluttered. To make your work appear cleaner, isolate the scan line that represents the center line.

To isolate the center line

- 1 Click and hold the X-scans layer button to open the menu.
- 2 Turn off the **Visible** option.
- 3 Repeat Steps 1 and 2 for the Z-scans layer. In the end, only the Y-scan lines should remain visible.
- 4 Choose **Pick > Object** and select the scan line that represents the center line.
- 5 Choose **ObjectDisplay > Hide Unselected**. All unselected scan lines are hidden - only the selected center scan line is visible. (To make the hidden lines visible again, choose **ObjectDisplay > Visible** from the menu).



Learning Objectives

In this section you will learn how to:

- Create curves and fit them to the scan lines.



Commit these steps to memory – later in the tutorial you will be asked to isolate a particular scan line or make a layer visible or invisible.

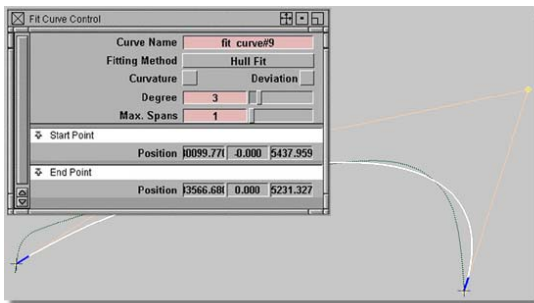
You may recall that when you were in the workshop you found it difficult to shape the center line in one step. To complete the model, you shaped three main surfaces (the front, middle, and rear) and completed the model by adding two blends. Following the workshop example, fit a curve to the top part of the center scan line. Use an automatic fitting algorithm, such as the **Curve Edit > Fit curve** tool, to undertake this part of the project.

To fit the top part of the center line using the **Curves > Fit Curve** tool

- 1 In the **Viewing Panel**, switch to the side view by selecting the middle arrow in the bottom row of arrows.

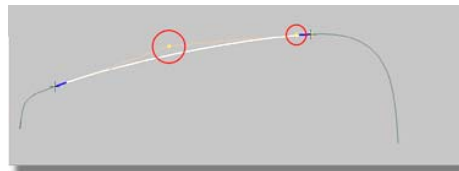


- 2 Double-click the **Curves > Text** tool to produce the options box.
- 3 Select the scan line that represents the center line and set the options in the Fit Curve Control as shown in the image below.

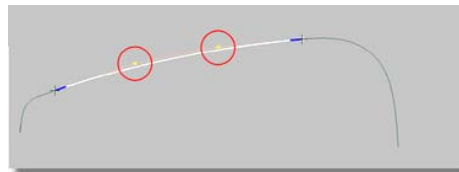
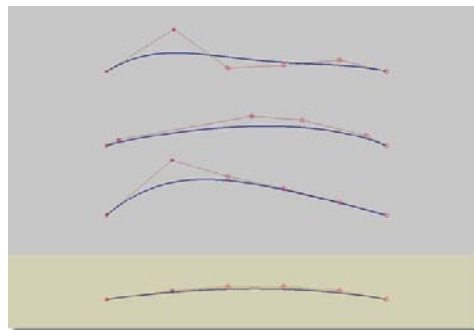


The **Curves > Text** tool selects the entire scan line, but initially you will be interested in selecting only the top part of the curve.

- 4 Pick the cross that lies adjacent to the blue manipulator and move along the scan line until only the top portion of the curve is selected.



Your curve should resemble the above image. As you gain more experience with surface modeling, you will learn to judge the placement of the CVs. Later in the tutorial, the term “Hull / CV distribution” will be used to describe the placement of CVs.

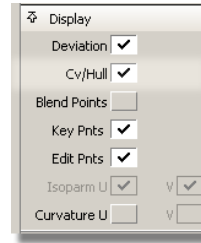


By moving the crosses and changing the fitting method, you can influence the CV distribution.

Another method for achieving a good CV distribution is to pick the CVs and move them to the desired position. However, this method is not recommended at this point in the modeling process as moving CVs will destroy the construction history of the curve.

- 5 Repeat Steps 2 – 4 for the front and the rear portions of the center line.

After fitting the three parts of the center line, your curve should resemble the image below.



To view all of the CVs associated with an object, click the box of the **CV/Hull** option located in the **Display** section of the Control Panel, so a check mark appears.

Next, blends will need to be created between the three main curves. Another semi automatic tool, the Blend curve, will be utilized to perform this task. Blend curves can be intimidating to the beginner, so for this reason you will be asked to use a limited number of the simpler options.

Creating blends between the main curves

To create the blends using blend curves

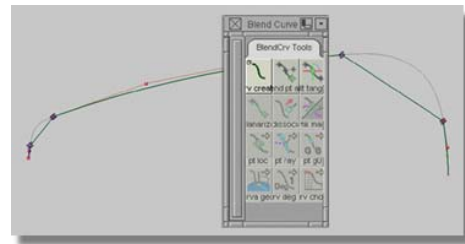
- 1 Click and hold down the Y-scan layer button to open the menu.
- 2 Choose **Set state > Reference** from the layer menu.
- 3 Choose **Curves > Blend curve toolbox** to open the toolbox.



- 4 Choose the **BlendCrv Tools > Blend curve create** tool from the toolbox. (Click the **BlendCrv Tools** tab to see the menu or click the icon).
- 5 Place a blend point (the first point of the blend curve) on the endpoint of the top curve.
- 6 Place the second blend point on the endpoint of the back curve.

A straight line will appear between the top curve and the back curve.

- 7 Repeat Steps 4 to 6 for the other side of the curve.

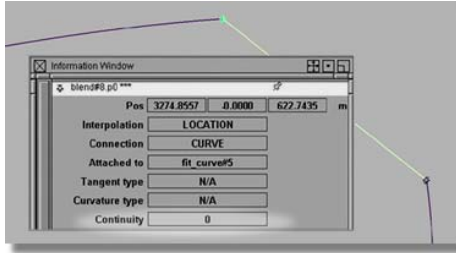


The number of blend points can be unlimited, but it should be understood that each new blend point increases the number of spans on the blend curve. Also, a blend point holds a vast array of information that defines the shape of the blend curve. A blend point is essentially a guide, or a point of reference, for a blend curve that could interact with a curve, a surface, an isoperimetric curve, or a curve-on-surface. To access the information associated with the blend point, open the Information window.



To use the Information window

- 1 Choose the **Pick > Point Types > Blend point** tool and select one blend point.
- 2 Choose the **Windows > Information > Information window** menu item.



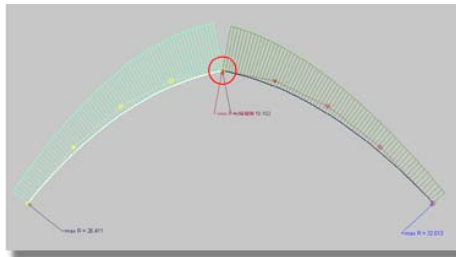
Pos	3274.8557	0.0000	622.7435	m
Interpolation	LOCATION			
Connection	CURVE			
Attached to	fit_curve#5			
Tangent type	N/A			
Curvature type	N/A			
Continuity	0			

The value for the **Continuity** option should be set to **0**. Continuity is a measurement of how two surfaces or curves connect.

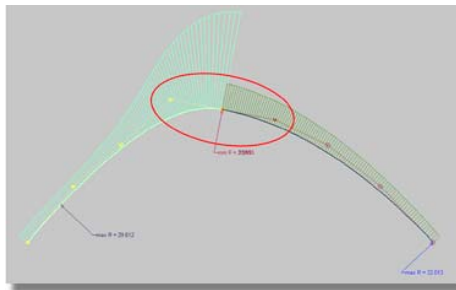
For the purposes of our model, the blend curve should appear as a bowed transition between the two scan lines. In order to change the blend curve, we will need to change the **Continuity** measurement to **2**.

An explanation of Continuity types

- **POSITION (G0)**
This type of continuity between curves implies that the endpoints of the curves have the same X,Y, and Z position in the world space. This is the minimum requirement for obtaining **G0**.



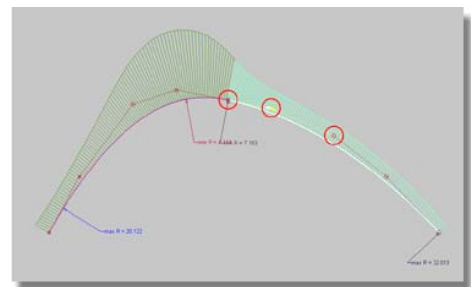
- **TANGENT (G1)**
This type of continuity between curves implies that the tangent CVs must be on one line.



- **CURVATURE (G2)**
This continuity type impacts the third CV of the curve. All three CVs have to be considered in order to maintain a smooth curvature comb.

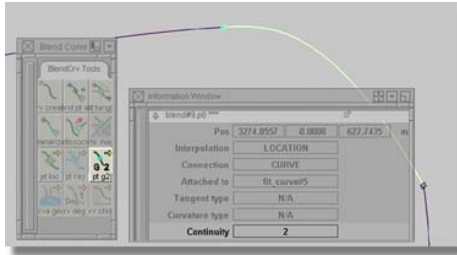


If a curvature comb does not have a smooth transitional line, further continuity levels can be applied but are outside of the scope of this tutorial. In order to improve the curvature comb, manually modify the position of the three CVs that constitute the **G2** continuity.



To change the constraint continuity of a blend point

- 1 Select one blend point.
- 2 Choose the **BlendCrv Tools > Constraint Continuity > Blend constraint G2** tool.

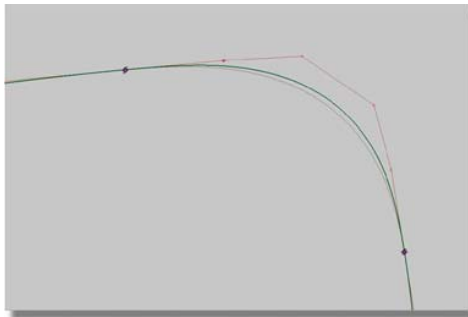


The blend curve changes from a straight line to a smooth transitional curve between the two scanned lines. Note also that the value for **Continuity** has changed to a **2 (G2)** in the Information Window. If the shape of the blend curve is not perfect, you will have an opportunity later in the tutorial to manipulate it.

- 3 Repeat Steps 1 & 2 for the remaining three blend points (adjusting continuity at each end of both blend curves).

To examine the proximity of the blend curve to the scan line

- 1 Choose **Pick > Nothing**.
- 2 Zoom into the scene until you have a clear view of the blend curve and the scan line.
- 3 Select the blend curve.
- 4 Turn on the CVs (**CV/Hull** in the Control Panel).



The CV distribution of the blend curve is very good, but the blend curve does not fit to the scan line. How could you correct this problem?

Method 1: Change the position of the reference curve endpoints.

Method 2: Use the manipulator to change the shape of the blend curve.

Before you make a decision about how to correct this problem, you should stop to consider some aspects of the work you have completed.

The CV distribution of the blend curve is satisfactory – so, there's no need to change it. That leaves you with the endpoints – because the top and rear curves still have their construction history, you should use small incremental movements to manipulate the endpoints.

To reactivate a tool's option box using the Query Edit tool

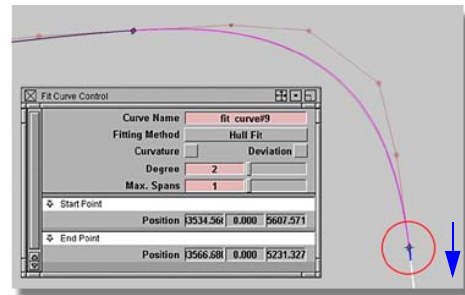
- 1 Choose the **Object edit > Query edit** tool.
- 2 Select the rear curve.

The Fit Curve Control window and the blue manipulators will appear again.

- 3 Move the upper cross down toward the end of the curve.

Because the blend curve is still attached to the curve (with **G2**), it will follow.

- 4 While you move the cross of the fitted rear curve, pay attention to how close the blend curve comes to the scan line.



At this point in the tutorial, you should be comfortable with using your eyes to judge the deviation to the scan line. Within the confines of this tutorial, your work does not have to be precise, but for situations where your work must be more professional, you will require the assistance of a measurement tool, such as a Locator.

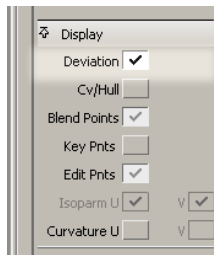
To use a Locator tool in measuring a curve-to-curve distance

The scan line has to be pickable.

- 1 Click and hold the Y-scan layer button to open its menu and choose **Set State > Pickable**.
- 2 Choose the **Locators > Deviation > MinMaxCrvCrv deviation** tool.
- 3 Select the scan line and the curve(s) you want to measure. More than one curve can be selected. The deviation between the selected items will be measured and appear as a locator.



In the Control Panel you can switch the deviation locator on or off by selecting/deselecting the **Deviation** checkbox (the curves need to be picked first).



- 4 Modify your curves and note how the deviation locator updates the deviation status.
- 5 After you are satisfied with the results, select and delete the deviation locator.

If you are still not content with the match between the scan line and the blend curve, you can explore another method for reshaping the blend curve.

Blend points are located at the ends of blend curves. Each blend point contains information that can be read in the Information window (**Windows > Information > Information window**).



For complete control over a shape, you should always turn on CVs in the Control Panel (**Cv/Hull**).

To use the blend curve edit manipulator in the Blend curve toolbox



- 1 Choose **Pick > Nothing**.
- 2 Pick the upper blend point.
- 3 Open the blend curve toolbox.



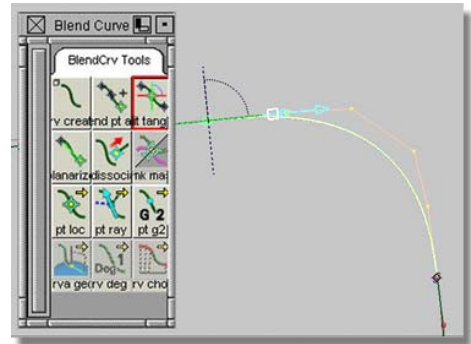
- 4 Choose the **BlendCrv Tools > Blend curve edit** tool.

A new manipulator will appear that features a blue sphere and a blue rectangle.

- 5 With the **left mouse button**, pick the sphere, hold down the mouse button, and move the mouse. Note the movement of the blend curve.
- 6 Repeat Step 5 using the rectangle.



When manipulating the rectangle, the second and third CVs move while manipulating the sphere will move just the third CV.



Up to this point in the tutorial, you have learned two methods for fitting a blend curve to a scan line. The first method changed the reference points. If the first method does not produce sufficient results, as a last resort, use the manipulator to change the shape of the blend curve.

- 7 Repeat the entire sequence for the front blend. In a real job environment where time is often a critical factor, when changing the connection quality of the blend point to **CURVATURE** quality (**G2**) you should simultaneously select both blend points to save time.

Take a moment to consider the work completed at this point in the tutorial.

You will recall that earlier in the tutorial you conducted a deviation control by hand and used your eyes to judge your work.

The next step is to use a curvature comb to check the smoothness of your curve connections.

To check the curvature of curves

- 1 In the Y-scan layer menu, choose **Set state > Reference**.
- 2 Select all of the curves.

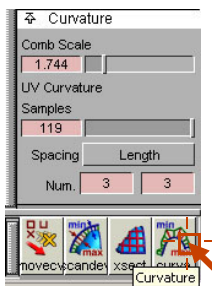


- 3 Choose the **Locators > Curve curvature** tool. Locators will appear that show curvature combs connected to the selected curves. Curvature combs are locators, and as such, you can access information about them through the menu item **Windows > Information > Information window**.

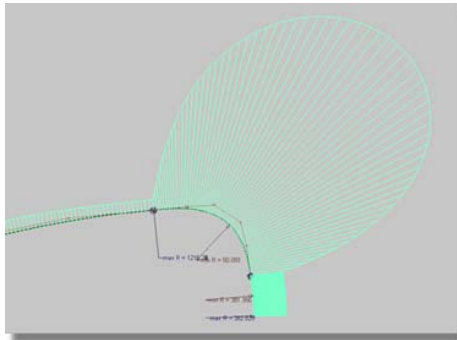
In most cases though, the curvature comb locator will not provide you with all of the information you may require. To gain more information, select the Curvature shelf from the Control Panel and change the Comb Scale value.

To change the Comb Scale value

- 1 Select the **Curvature** button from the Control Panel to open the **Curvature** shelf.
- 2 Change the values for the **Comb Scale** and the **Samples** options.



Having changed the Comb Scale and Samples values, your curve should resemble the image below.



The comb shows a significant jump in values at the position of the blend curves (not a smooth transitional curvature comb). If you were to leave the curves in their current state, the end result would take into account the distortion of values as pointed out by the curvature combs. To remove any curvature distortions you should adjust the combs in

a finite fashion. As the manipulation of the curves is a complex task, be careful to adjust the combs in small increments. In fact, it could take you a matter of years to perfect the art of manipulating curves. However, in the interests of time, there are some hints that should speed-up the process.

Factors to consider when manipulating curves

- Watch the curvature plot of the top curve. It has a clean arc because the CVs are placed at regular intervals.
- Try to increase the curvature at the end of the top curve. To accomplish this task, directly manipulate some of the CVs.
- Moving the second CV always has a significant impact. Manipulate it very slowly in order to keep the close deviation to the scan line that you have already achieved.

To model CVs directly

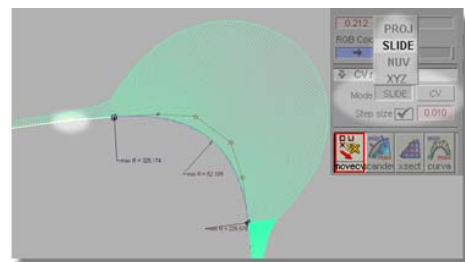
- 1 Pick the top curve.
- 2 From the menu, choose **Delete > Delete construction history**.
- 3 You will be prompted to make sure that you want to delete the construction history for the curve. Click **YES** to confirm.

The top curve will no longer have a Fit Curve history.

- 4 Select the highlighted CV shown in the image below.
- 5 At the bottom of the Control Panel, select the **Move CV** tool.
- 6 In the CV Move shelf, set the two values associated with Mode to **SLIDE** and **CV**.

The selected CV will now appear with two arrows that point in the direction of the available movement associated with the CV. The direction will always point toward the next CV.

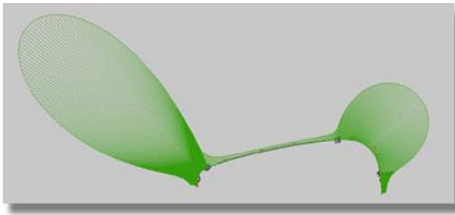
- 7 Pick one arrow and move the CV slightly.



- 8 Watch the curvature and how the curvature comb changes.

Remember, the objective of this exercise is to strike a balance between a smooth transitional curvature comb and a close fit to the scan lines. As you experiment with different strategies and methods for achieving the desired results, you may find that you will need to correct the endpoints of your first three curves.

Your finished curvature comb should resemble the image below. It may require a significant investment in time to achieve the same results but the experience you gain from the exercise will help you later in your surface modeling career.



To clean up your work

- 1 Choose the **Delete > Delete all locators** menu item. All of the green curvature combs should disappear.
- 2 Choose **Layers > New** to produce a new layer.
- 3 Double-click the new layer, then type "Center Line CRV" and press Enter.
- 4 With the new layer still selected, pick all of the new curves that represent the center line.
- 5 Click the new layer button, hold down the mouse button and move the mouse down to **Assign**. The selected geometry will be assigned to the new layer.

- 6 Using the same technique as Step 5, make the new layer's contents invisible by moving the mouse down to **Visible** in the new layer menu. The check mark beside the option will disappear and the geometry assigned to the layer will become invisible.
- 7 From the menu, choose **ObjectDisplay > Visible** to make all of the Y-sections appear.
- 8 Repeat Step 6 to make the layer Y-scan invisible.
- 9 Save your work.

At this point in the tutorial, you should have an empty screen.

Summary

- Blend points have special information that can be accessed through the **Windows > Information > Information window** menu item, or can be changed via the options available in the Blend curve toolbox.
- Curve fitting is an intricate process that should lead to striking a balance between a smooth transitional curvature comb and a close deviation to the scan line.
- Curve positions are never fixed. Blend curves can change the endpoints of main curves.

Following the process detailed at the beginning of the tutorial, you can define the shape of the other two directions (the front surface, or X- scans, and the top surface, or Z-scans).

While fitting the new curves you will be introduced to some new methods. In general though, you will be able to use the same processes detailed in this section to complete the next step.

Fitting Curves to X-scans

X-scans (X-scan lines) are quite different than Y-scans.

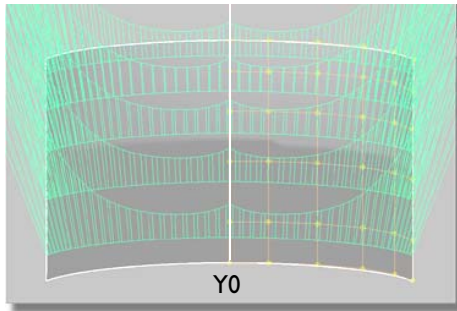
Some characteristics of X-scans

- X-scans run perpendicular to the center line, whereas Y-scans run parallel to the center line.
- modeled X-scans are symmetrical, in that one half is the same as the other half.

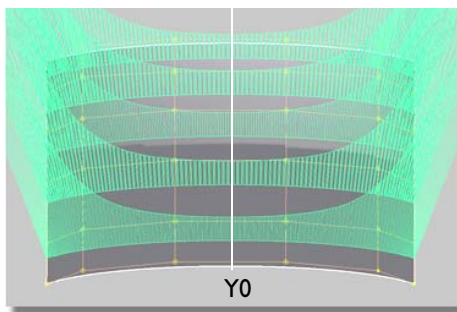
Because of the X-scan characteristics, it is possible to model half the model and mirror the other half.

Mirroring saves time, but it can also produce a problem that must be addressed. Running along the Y-plane at the Y0 position, whole surfaces, such as the top surface, are seamless. On the other hand, when employing the "half-side-modeling" method, two surfaces and a connection seam are created. Connection seams lead to modeling problems with curvature combs.

For example, the image below shows a surface that covers the right half of the model. The left half of the model was mirrored from the right half. Note that the curvature combs have a seam crossing the center line. This seam can be modified, but special attention will have to be paid to the manipulation of the surface.



In contrast, the image below shows one surface covering the entire top of the model. The curvature combs crossing the center line are smooth, and as a result, you will never have to check the appearance of the curvature comb crossing the Y0 position.



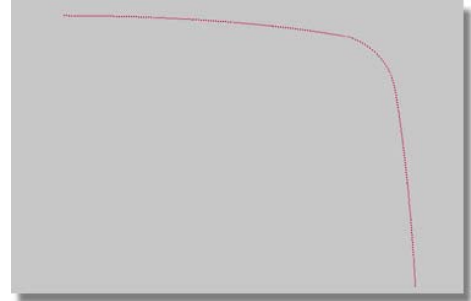
To avoid the problems created by mirroring, all surfaces that cross the center line should be constructed as one surface.



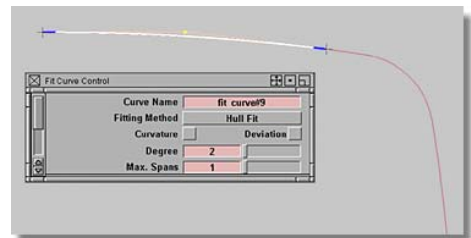
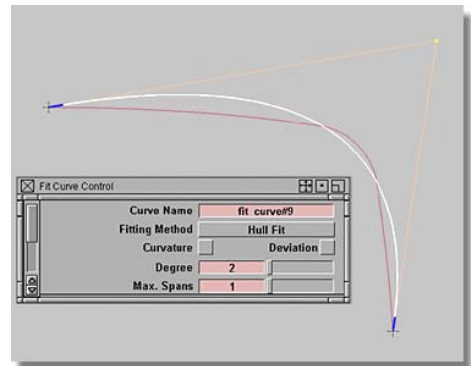
This is not an absolute rule. There are other models and situations where it may be better to employ the mirroring strategy.

To fit a curve that crosses the center line

- 1 Make the scan lines from the X-scan layer visible and pickable. (Use the **Visible** and **Set State > Pickable** menu items for the X-scan layer).
- 2 Select one scan line from the middle portion and isolate it. (Use the **ObjectDisplay > Hide Unselected** menu item).



- 3 To fit a curve to a scan line, double-click the **Curves > Text** tool to produce the option box.
- 4 Set the options as shown in those in the image below.
- 5 Use the **Curves > Text** tool in the same manner as detailed in “Establishing and creating the center line” section.



Once you have created the curve and matched it to the scan line, you can use it as a guide.

- 6 Choose **Pick > Nothing**.



- 7 Select the new curve.
- 8 From the menu, double-click **Edit > Duplicate > Mirror** to produce the Mirror Options box.
- 9 Set the **Mirror Across** option to "XZ" and press **Go**.

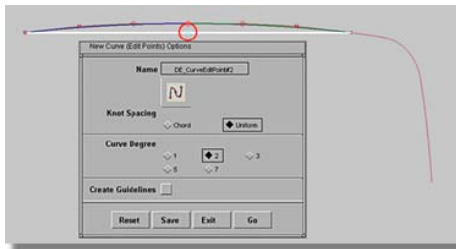


Two points have now been produced, one at either side of the model, each with a corresponding position relative to the center line. The next step in the procedure will be to create the real curve.



- 10 Double-click the **Curves > New curves > New Curve by Edit Points** icon to produce its option box.
- 11 Set the options as shown here.

Set this parameter...	To this value
Knot spacing	Uniform
Curve degree	2
Create guidelines	off



- 12 Create a straight curve between the two endpoints.



Use the Magnet tool (upper right corner of the display) to snap the new CVs exactly to the endpoints.



- 13 Choose **Pick > Nothing**.

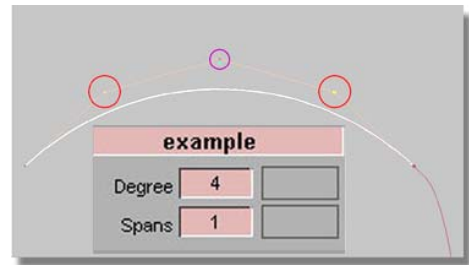
- 14 Delete the helper curves.
- 15 Select the middle CV and move the CV in the Z-direction to match the shape of the scan line.

As you manipulate the CV in the Z-direction, you may notice that you cannot model the shape of the scanned line with just one free CV. Eventually, you will need more CVs, but not before giving some thought to the maximum number of CVs you will require. To tackle this question, always start with the lowest degree (number of CVs) and increase the value in small steps. Employing a lowest-to-highest degree strategy should ensure that you do not overbuild your model.

To increase the number of CVs of a curve

- 1 Make sure that the curve is selected.
- 2 Turn on the CVs (**Cv/Hull**) in the Control Panel.
- 3 In the **Degree** text box located in the middle of the Control Panel, type in the value **4** and press Enter.
- 4 Click the **Accept** button in the lower right corner of the window.

You now have more CVs to help you achieve the shape of the scan line.



With the increase in CVs there is also an increase in the freedom of movement. When moving CVs you should remember to always move corresponding CVs at the same time, otherwise, you will lose the symmetry of the curve.

Going forward with this exercise, you will encounter a problem when trying to change the position of the marked CV in the Y-direction. One solution to this problem is to select the CVs you intend to move on both sides of the center line and then center the pivot point. You will then be free to move the CVs using a non-proportional scale.

To move CVs using a non-proportional scale



1 Choose **Pick > Nothing**.

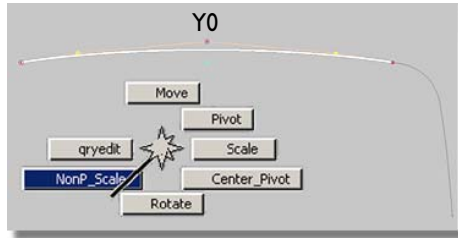


2 Select the CVs highlighted in the image above.

3 Choose the **Transform > Local > Center pivot** tool. Note that the green pivot point jumps closer to the center CV. The pivot point marks the balance point of the selected CVs. Your local source point for the next movement will be placed at the new location of the pivot point.

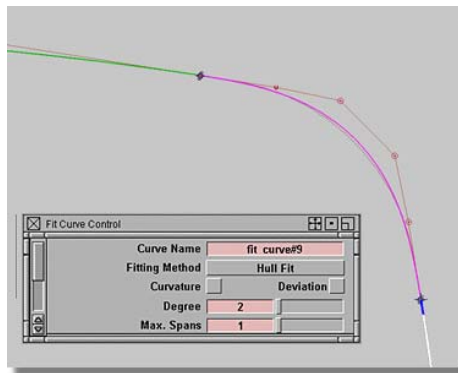


4 Choose the **Transform > Non-p scale** tool and use the middle mouse button to move both CVs in the Y-direction, away from the Y0 position.



You will now be able to fit the curve to the scan line, but don't consume too much time measuring the deviations between the scan line and the curve. Instead, concentrate on trusting your eyes and developing an understanding of the CVs role.

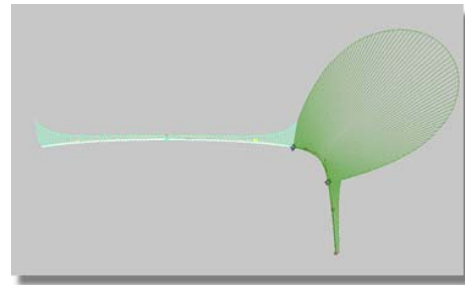
After completing the top curve, continue creating the missing parts of the X-scan line. Use the same methods you learned when creating the center line (changing the endpoints of the curves, and modifying the blend curve using the manipulator).



Remember to check the curvature comb of your X-curves by selecting all the curves and then using the **Locators > Curve curvature** tool.



Also, take care when polishing the curvature plot that you limit your movement to the non-proportional scale of the CVs on the top curve. To avoid destroying the symmetry of the curve, you should not use the **SLIDE** command if the curve runs across the Y0 position.



Your efforts should resemble the curve in the image above.

To save your work

- 1 Select all of your new curves and save them to a new layer named "X CRV".
- 2 Make sure that all the X-scans are visible again.
- 3 Make the X CRV layer and the X-scan layer invisible.
- 4 Save your work.

At this point in the tutorial, you should have an empty screen.

Summary

- In this section you were introduced to the curvature plot and its relationship to half-modeling techniques.
- As well, you were taught how to avoid a curvature peak in the plot that crosses the center line by building curves and surfaces across the middle.
- But perhaps most importantly, you were instructed to always move CVs in groups of corresponding pairs to avoid losing the symmetry of the curve. The best practice for moving multiple CVs is to select the CVs as a pair, center the pivot point, and use the non-proportional scale for horizontal movements.

Fitting Curves to Z-scans



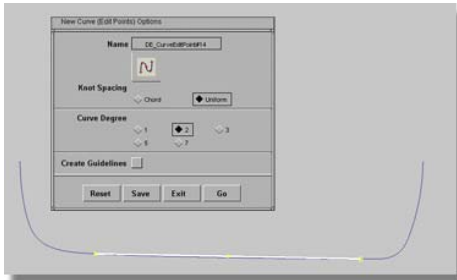
A new tool, **Object Edit > Align > Align**, will be used to fit a scan line from the Z-scan layer. The option box of the **Object Edit > Align > Align** tool is quite complicated, but most of the options pertain to matching surfaces. As you are concerned with curves, you will only need to interact with a few of the options.

To create a set of curves using edit point curves

- 1 Set the Z-scans layer to **Visible** and **Set state > Pickable**.
- 2 Isolate one scan line that encompasses the model.
- 3 Hide the unselected scan lines. (Use the **ObjectDisplay > Hide Unselected** menu item).



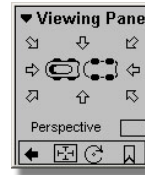
- 4 Create a degree 2 edit point curve at the middle portion of the scan line by snapping the endpoints to the scan line. (Use the **Curves > New curves > New Curve by Edit Points** tool).



- 5 Pick the middle CVs and move the CVs in the Y-direction until you fit the shape of the scan line.

With flat shapes, you may find it difficult to judge the shape of your curve. To get a better view of your work, go to the **Viewing Panel** by pressing **Shift + Alt**. Inside the **Viewing Panel**, examine the four icons in the bottom rectangle. Make sure that the box beside the **Perspective** option does not contain a check mark. Inside the bottom rectangle, choose the square icon. You will now be able to dolly your view in a non-proportional manner that should

provide for a better view of how your curve fits to the scan line.



To use the icons in the Viewing Panel

- 1 Press **Shift + Alt** and hold down the buttons.
- 2 Make sure that the **Perspective** option does not contain a check mark.
- 3 Choose the square icon. The icon will turn white to show that it is engaged.
- 4 Keep holding down the **Shift + Alt** keys. (The **Viewing Panel** must remain open to execute the view change).
- 5 Use the mouse buttons to scale the view.



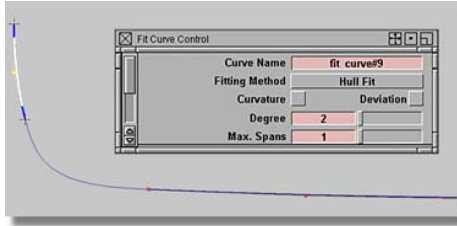
The **right mouse button** scales the view both horizontally and vertically, the **middle mouse button** operates on the horizontal scale, and the **left mouse button** is reserved for the vertical scale.

- 6 To return to the original view, choose the **Perspective** option and then remove the check mark. The view should return to the natural scale in the orthographic view.
- 7 If the non-proportional view is not sufficient, choose the circled arrow icon at the bottom of the **Viewing Panel** to spin the view. To return to the original view, use the black arrows that surround the car icons in the middle of the **Viewing Panel**.
- 8 To fashion the front/rear curve, use the same technique employed on the X-scans.

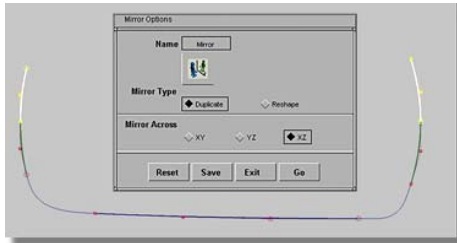
Tips for creating a set of curves using edit point curves

- Use the **Curves > Text** tool.

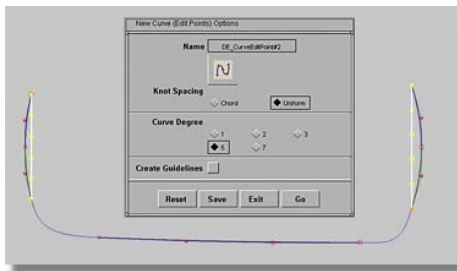




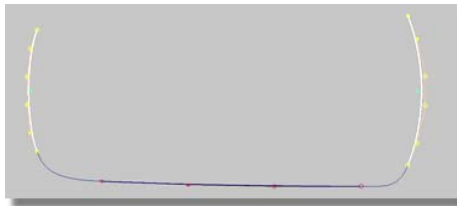
- Mirror the fitted curves.



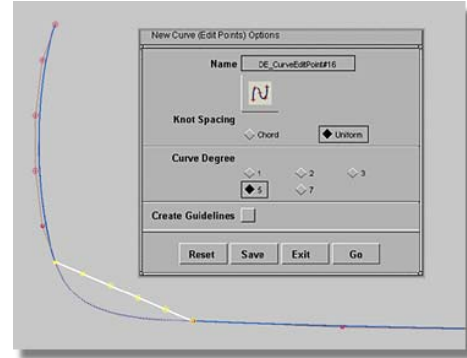
- Create two degree 5 edit point curves.



- Shape the degree 5 curves to fit the scan line. Remember to move corresponding CVs to maintain the curve's symmetry. As well, when moving CVs in the Y-direction, use the non-proportional scale and center the pivot.



When creating the transition between the front portion of the curve and the middle portion of the curve, use a degree 5 edit point curve to bridge the endpoints.

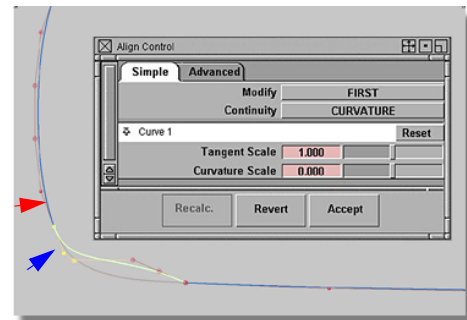


After completing work on the Z-scan line, the degree 5 edit point curve looks similar to the curve used in blending the center line. Note that the current straight line is not a blend curve. Instead, it is a degree 5 edit point curve that allows for the use of the **Object Edit > Align > Align** tool for shaping the curve to the blend points.



To use the Align tool for aligning two curves

- 1 Choose the Z-scan layer option **Set state > Reference**.
- 2 Double-click the **Object Edit > Align > Align** tool icon to produce the option box.
- 3 Select the edit point curve at the marked point (blue arrow) to align the curve beginning with the selected end.
- 4 Select the top reference curve at the marked point (red arrow) to align the first picked curve to the second picked reference.



- 5 Set the **Object Edit > Align > Align** tool options as shown above.

By setting the **Continuity** option to **TANGENT**, you will notice that just the first and the second CVs are highlighted in yellow. If you change the **Continuity** to **CURVATURE** you will notice that the third CV is highlighted as well.

- 6 Repeat Steps 3-5 for the other side.

The **Continuity** level determines how many CVs are highlighted, or influenced. This knowledge is crucial to understanding the alignment of surfaces later in the tutorial.

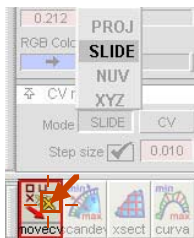
The basic concepts behind the primary Continuity settings

- 1 **POSITION** means the first CV will be moved to the reference.
- 2 **TANGENT** means the first and the second CVs have to be moved to achieve the quality.
- 3 **CURVATURE** means that, in addition to the first and second CVs, the third CV will also have to be moved to achieve the quality.

Now, it should be clear that in order to achieve curvature continuity on both sides of the curve, a minimum number of 6 CVs is required. Use a degree 5 single span edit point curve to achieve these results.

To direct model a curve

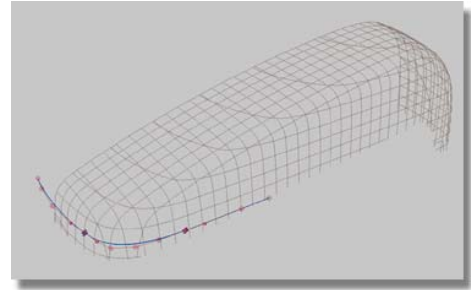
To fit the curve to the scan line you can now use the **SLIDE** option in the **CV Move** shelf located at the bottom of the Control Panel. After sliding a CV, the **Object Edit > Align > Align** tool will always bring the CV back into alignment. By proceeding in controlled steps, you will achieve a proper deviation.



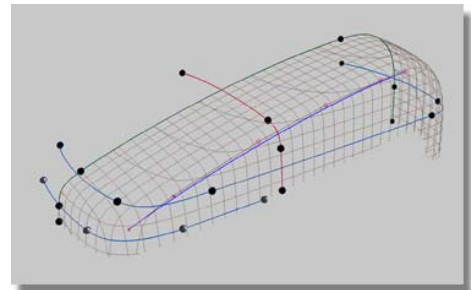
Also, don't forget the possibility of changing the start points of the reference curves. Click the first CV of the reference curve and move the CV while pressing **Ctrl + Alt** (curve snap) along the scan line.

Three additional curves will have to be fitted to the Z-scan lines. The new curves will serve as guides

for developing the front end surface and the transition surface. Use the methods previously described in this section to fit the Z-scan lines.



Your completed curves should resemble the image below - the spheres mark the endpoints of the curves.



To clean-up your work

- 1 Create a new layer and name it "Z CRV".
- 2 Assign the curves to the layer.
- 3 Make the scan line layers invisible.
- 4 Make all new curve layers visible.
- 5 Save your work.

SURFACE CREATION

Introduction to Patch Layouts

Fitting curves can be a time-consuming endeavor, and yet, even at this point in the tutorial your surface edges do not have the same X, Y, and Z directions as the input data. Additional curves are required to construct a proper surface. The new curves will need to be fitted and monitored for their deviation from the scan line. But instead of repeating the same tasks detailed in previous sections of the tutorial, you can take a break from fitting curves by learning about another method called Patch Layouts.

A Patch Layout is a master plan of the surfaces that cover the model. A Patch Layout shows which edges will need to be trimmed, how many surfaces in total will be required to complete the project, and how big they will need to be. For the beginner, most of the hard work happens before the point in the project where a Patch Layout can be generated. After generating the Patch Layout, you can concentrate on polishing and refinishing the surface to achieve a closer fit to the scan line. Once you become more familiar with structuring surface models, your workflow may change.

The subject of correct Patch Layout procedures is larger than the scope of this tutorial.

To learn more about Patch Layouts, examine surface data sets and experiment with taping surface edges onto physical models. These procedures will help you to think about the surface modeling process like a professional.

When approaching a new modeling assignment, try to imagine building the model by hand, or sketch ideas for how you would like to structure the surfaces. In situations where more complicated surfaces are required, such as ball corners, it may help to make small clay models by hand to rough out a tangible guide.

Learning Objectives

In this section you will learn how to:

- Understanding the **theoretical line** and helper surfaces.

The Importance of Helper Surfaces

In keeping with the classic model construction method detailed at the beginning of the tutorial, you will now develop surfaces using the center line.

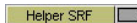
To use the Draft tool



- 1 Open the wire file `First Surfaces.wire`.
- 2 Pick the scan lines and use the **View > Look at** tool.
- 3 Make sure you are in the orthographic window and that the Perspective option is not checked.
- 4 Set all scan layers to **Set state > Reference** and isolate the top curve (middle portion) of the center line. You will find the curve in the “aw y CRV” layer.

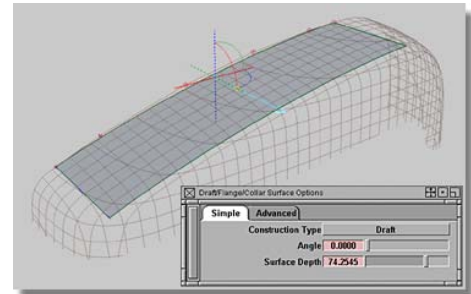
Using the selected curve in conjunction with the **Surfaces > Draft surfaces > Draft/flange** tool, you will be able to quickly create a surface. The **Draft** tool is a fast and easy way to create surfaces for defining the initial shape of the model. In general, surfaces should be used, instead of curves, to define the initial shape of a model. The surfaces constructed in this tutorial, created using the **Draft** tool, act as guides, or helpers, to produce the final, more professional surfaces.

- 5 Create a new layer called “Helper SRF”.
- 6 If the new layer is not highlighted in yellow, click the layer button until it changes to yellow.



As long as the layer is highlighted in yellow, all new geometries will be assigned to that layer.

- 7 Double-click the **Surfaces > Draft surfaces > Draft/flange** tool to open the option box.
- 8 Select the top curve of the center line.
- 9 Press the **Go** button.
- 10 Adjust the manipulator until you produce a surface similar to the image below.
- 11 Choose **Pick > Nothing**.



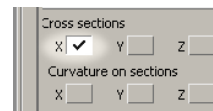
The **Surfaces > Draft surfaces > Draft/flange** tool can create a flat surface from a curve, a surface edge, a curve-on-surface, or an isoparametric curve. The draft surface consists of an angle, a length, and a direction – each of which is related to the current construction plane and can be manipulated in the Draft Surface Options box. Additionally, the **Surfaces > Draft surfaces > Draft/flange** tool produces a manipulator (a big cross) for changing the direction and angle of the surface. Another smaller manipulator is also produced that features a blue circle and a red flag at the end. The red flag changes the length of the draft while the blue circle changes the angle. Each manipulator allows values to be typed into the Prompt line at the top of the screen.

You can choose **Flange** by clicking the **Draft** button adjacent to the **Construction Type** option.

Flange is similar to **Draft** but the calculation of the direction is different. When a surface related object (an edge, a curve-on-surface, or an isoparametric curve) is selected, the normal of the surface is used to calculate the direction of the flange.

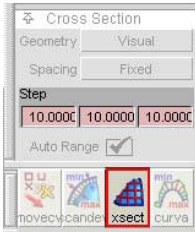
To use the cross-section tool

- 1 Select the draft surface, activate the X-Cross-Section by clicking the **X** checkbox in the cross-sections portion of the Control Panel.



- 2 Check the spacing by choosing the **Cross sections** tool at the bottom of the Control Panel.

In the Cross Section shelf, there are three values for the **Step** option (X, Y, and Z). Make sure that the draft Step values equal the Step values for the scan line – for our model, the draft Step values should be set to **10**.



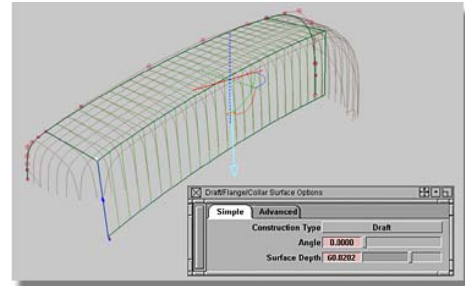
To complete this section of the surface modeling process, create the next draft surface by choosing the edge of the previous draft. The new draft surface will have to follow the Z-direction.

Continue using the Draft tool to create a new surface

- 1 Create the next draft surface by picking the long edge of the completed draft surface. The new draft surface will be constructed in the Z-direction (pick the blue line on the big cross).
- 2 To fit the new draft surface to the scan lines, adjust the angle related to the Z-direction by using the blue circle on the small blue

manipulator. The **Angle** option value in the option box will update based on the movement of the manipulator, or an **Angle** value can be entered manually into the option box.

- 3 Activate the Cross-Sections for the new draft surface as well. (If there is already a check mark in the X box in the Control Panel, you will need to turn it off then on again).



Understanding and Refining the Theoretical Model

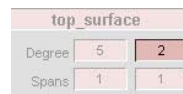
A theoretical model is a trimmed model without any fillets. The model has sharp, true edges. By examining a variety of consumer products, it is possible to see how fillets are the prominent aspect of the design. The fillets are said to flow from the theoretical model. As well, if you rotate a completed model in the sunlight, note how there are strong character lines highlighted by the sun – these lines define the shape of your model. To achieve fluid fillets and strong character lines, the quality of the theoretical model must equal the expected quality of the finished model.

At this point in the tutorial, the model has a pointed theoretical line that was determined by creating the two draft surfaces. Examine the theoretical line and the two surfaces to see how closely they fit to the scan lines. To achieve a better result, try adjusting the length of the first draft surface and the angle of the second draft surface.

In regards to fitting the top surface, because the top surface is flat it will need to be shaped in order to fit to the scanned line. To shape the top surface, delete the construction history (draft), increase the flexibility (degree) of the surface, and direct model the surface.

To increase the degree of a surface

- 1 Choose **Pick > Nothing**.
- 2 Select the top surface.
- 3 In the Control Panel, turn on the CVs (**Cv/Hull**).
- 4 In the Control Panel, increase the **Degree** value (in the V direction) from **1** to **2**.



- 5 Press Enter.



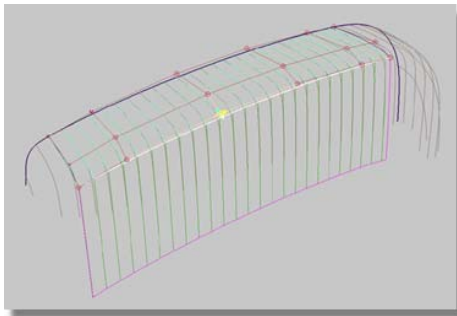
- 6 You will be prompted to confirm that you really want to delete the history. Press **YES** to confirm.
- 7 Press the **Accept** button.

The top surface now has a Degree value of **2** in the V-direction and ensures the flexibility required to direct model the surface. To execute the direct model process, move the hulls and single CVs in such a manner that the green cross-section fits flush to the scan lines. At the same time, the second draft surface still has history and will always update when changes are applied to the top surface. When modeling the top surface, remember to check for symmetry issues.

To direct model the surface



- 1 Choose the **Object edit > Align > Symmetry Plane Align** tool.
- 2 Pick the top surface on the edge that meets the center line. A selection box will appear because SurfaceStudio detects the surface and the center line curve at the same time. Choose the surface. You should see a collection of blue lines that highlight the surface as being symmetrical to the plane at the Y0 position. The **Object edit > Align > Symmetry Plane Align** tool created history that will maintain the symmetry of the surfaces. If you move the CVs of the first two hulls in the Z-direction, the corresponding CVs will follow. Before using the tool, make certain that the **Project for Position** option is activated in the Symmetry Plane Align tool's option box.
- 3 Move the opposite hull down to achieve a better fit to the scan line.
- 4 Move the middle hull along the Y-direction to find a better fit.
- 5 To fit the second draft surface to the scan lines, choose single CVs and move them via the **Move CV** tool at the bottom of the Control Panel, with Mode set to **SLIDE**.



The objective of this section of the tutorial is to find the theoretical line by using simple techniques involving simple surfaces. The first priority should be to fit both surfaces to the scan lines, and then examine the theoretical line from a number of views.

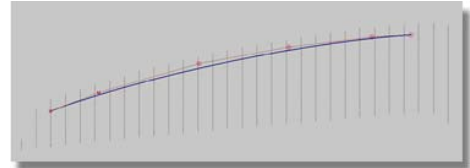
To examine the theoretical line

- 1 Save your work.
- 2 To make the comparisons easier, duplicate one surface edge to create a curve that represents the theoretical line. (Use the **Curve Edit > Create > Duplicate curve** tool).
- 3 Isolate the curve using the **ObjectDisplay > Hide Unselected** menu item.
- 4 Turn on the CVs of the curve (**Cv/Hull** in the Control Panel).

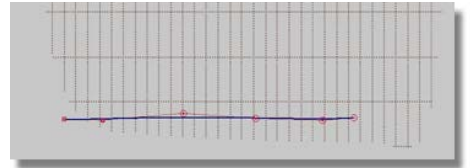


Compare your theoretical line to the views detailed below.

The theoretical line looks good from the side view.

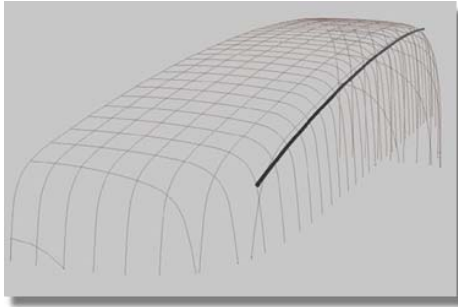


However, the theoretical line does not look very good from the top view. Remember the criteria of the CV distribution in the curve-fitting section.

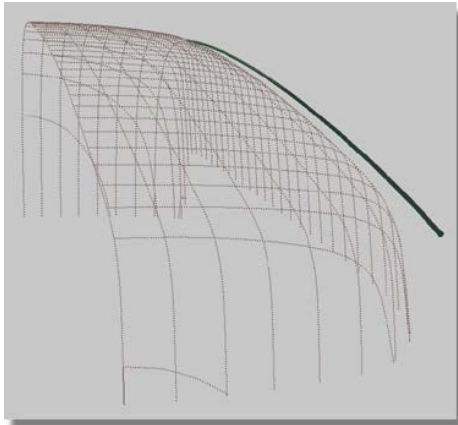


If the side and top views are acceptable, this is not a guarantee that the Perspective view is acceptable as well. As a basic rule, you must examine the theoretical line by tumbling the line in the Perspective view similar to the images below.

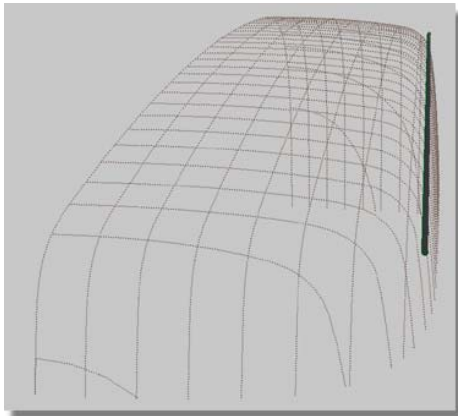
In the image below, note that the viewing position makes the theoretical line appear concave.



In the image below, note that the viewing position makes the theoretical line appear convex.



When tumbling between the concave and convex extremes, there must be a specific position where the view of the theoretical line has planar characteristics. See the image below for an example.



To achieve planar characteristics for the theoretical line that resemble the image above, pressure the

curve using the **Curve Edit > Curve planarize** tool. If technical restrictions do not allow for the use of the **Curve Edit > Curve planarize** tool, proceed with your existing theoretical line. The technique of pressuring curves is not a fixed rule, but rather, a guide for helping to define the feature lines that dominate the shape of a model.



Criteria for the theoretical line

- The surfaces that build the theoretical line must fit to the scan lines.
- From the top view, the theoretical line must have an even shape (criteria of CV distribution).
- From the side view, the theoretical curve must be fluid and properly aligned.

Solutions for meeting the theoretical line criteria

- Fit the surfaces, used to build the theoretical line, to the scan lines.
- Pressure the theoretical line in a plane. (A special function will be introduced to help you complete this task).
- Correct the theoretical line in each view without losing the planar character to achieve a better fit of the surfaces to the scan line. (Use the **Move CV** tool in the Control Panel, set to **SLIDE** or **NUV**).

A theoretical line is more than just a curve. A theoretical line, in a wider sense of the definition, relates to the edge of a surface. When scan lines are absent, it is a difficult task to model from a curve because the theoretical line will have no scan lines to act as guides. When working with surfaces that are close to the scan lines, the edge of the surfaces will show the theoretical line.

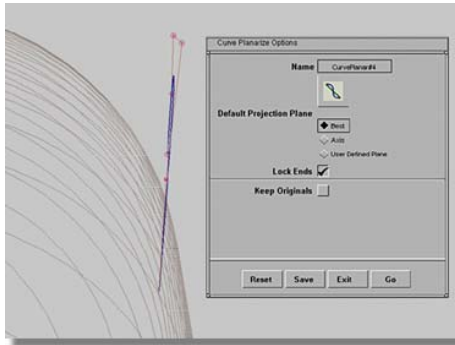
At this point in the tutorial, your duplicated curve should be fairly close to the theoretical line. However, the planar criterion is not fixed and it will require a new function to correct the issue.



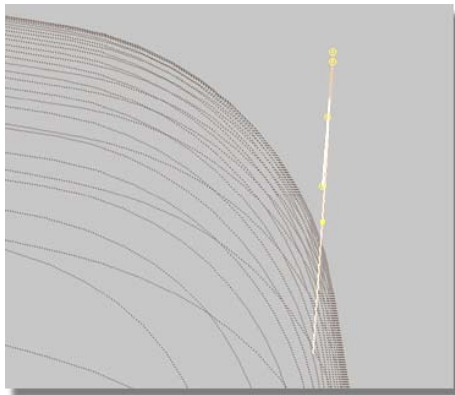
To planarize a curve

- 1 Double-click the **Curve Edit > Curve planarize** tool to produce the option box.
- 2 Set the options as follows.

Set this parameter...	To this value
Default projection plane	Best
Lock ends	on
Keep originals	off



- 3 Press the **Go** button.
- 4 Pick the curve representing the theoretical line. The **Curve Edit > Curve planarize** tool produces a new curve that differs slightly from the original in that it fits correctly to the plane. If required, modify the new curve using the **Control Panel > Evaluate > Move CV** tool. Because the new curve was generated with the **Curve Edit > Curve planarize** tool, the curve will remain planar.

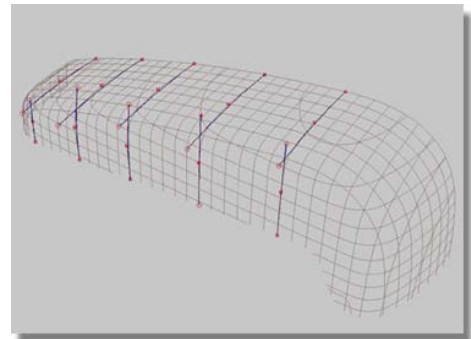


- 5 Create a new layer, name it "Theoretical line" and assign to it the planarized curve.
- 6 Save your work.

Establishing a fundamentally sound theoretical line is crucial to the success of the surface modeling project. The theoretical line provides the foundation for the construction of the surface model. As well, remember that it is equally important to maintain a smooth theoretical line in order to construct quality fillets.

Another method for creating a theoretical line involves the use of blend curves. While blend curves are a fast procedure and offer a high degree of history, they also lead to errors in the model. Because blend curves produce multi-span curves, the fundamental base for the entire surfacing process can be damaged. As a general rule, the geometry, or number of spans in a model, should always be kept to a minimum to ensure professional results.

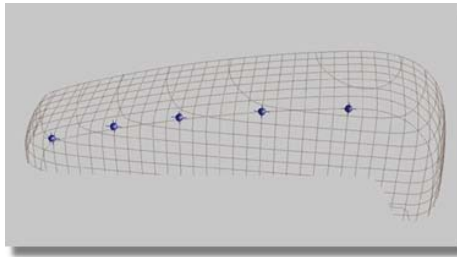
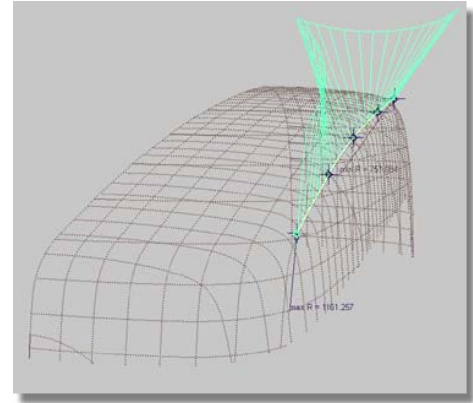
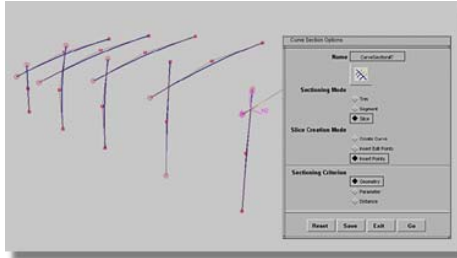
Fit curves to some scan lines. Extend the curves so that they intersect.



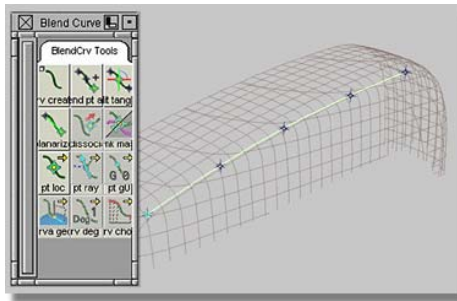
Create geometry points on the intersections. Double-click the **Curve Edit > Curve section** tool and set the options as follows.



Set this parameter...	To this value
Sectioning mode	Slice
Slice creation mode	Insert points
Sectioning criterion	Geometry



Create a blend curve by selecting all geometry points. Check the blend curve in the Control Panel to determine the number of spans and degrees. A multi-span curve has been produced. The blend curve is the theoretical line.



Examine the curvature plot of the blend curve, and then planarize the curve.

Summary



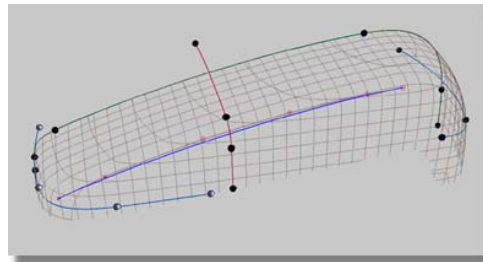
- Check your model before beginning the fillets. The edges of the trimmed model must be clean as it is not possible to correct a model using the various options in the **Surfaces > Surface fillet** tool option box.
- Many curves that define feature lines are planar in a special view. Once you have achieved an acceptable shape, planarize the curve to refine the shape.
- When modifying planar curves, the planar characteristics must be maintained. Use the **SLIDE** or **NUV** options in the **Control Panel > Evaluate > Move CV** tool. The **NUV** option works on curves, but does not maintain planar characteristics on surface edges.

CONSTRUCTING THE MAIN SURFACES

Extending the Theoretical Line

When building the main surfaces, the transitions (fillets and transitional surfaces) are very useful tools for evaluating the shape of the main surfaces.

At this point in the tutorial, your model should resemble the image below, complete with fitted curves and a theoretical line.



Construct the front, rear, top, and side surfaces.

In the above image, the spheres denote the end of the curves and help to visualize the area where the main surfaces will have to fit the scan lines. Because the length of the top surface does not match the length of the side surface, the theoretical line will have to be extended. Once the theoretical line has been extended, the side surface can be constructed. The side surface will be the first surface constructed because the theoretical line extends beyond the top surface.

To extend a curve

- 1 Open the file entitled `Main Surface.wire`.
- 2 Isolate the theoretical line (found in the "aw theo.line" layer).
- 3 Double-click the **Object edit > Extend** tool to produce the option box.
- 4 Set **Object edit > Extend** options as follows.

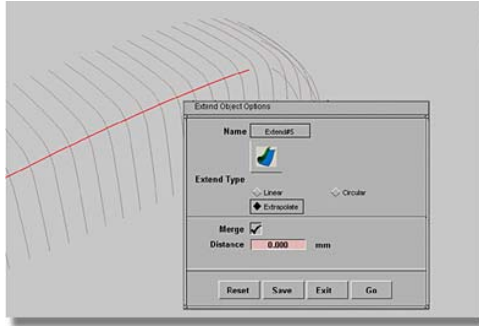
Set this parameter...	To this value
Extend type	Extrapolate
Merge	off
Distance	0.000



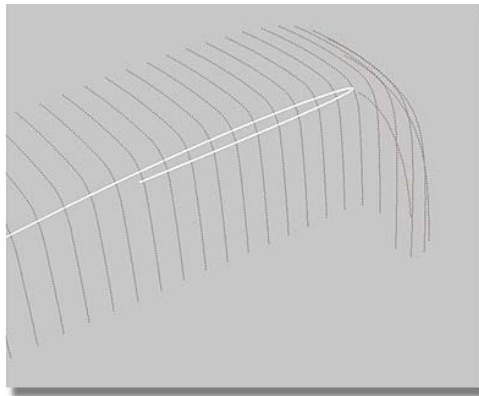
- 5 Press the **Go** button at the bottom of the **Object edit > Extend** tool's option box.



Use the options to select the end of the theoretical line and allow for movement to be executed by the left mouse button.



As shown below, curves can sometimes react to extensions in a different manner than intended.



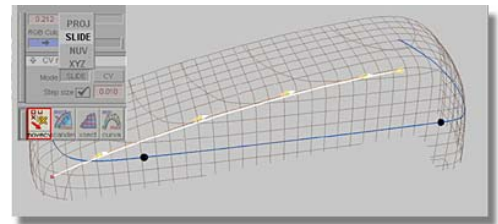
To return the curve to its pre-extension form, enter a value of **0** in the Prompt line at the top of the screen.

> Use mouse or keyboard to enter extend distance: Extend length: 595.944



Extend the theoretical line using the **Control Panel > Evaluate > Move CV** tool set to **SLIDE**. Using the **Control Panel > Evaluate > Move CV** tool will ensure that the curve will stay planar and that the shape will not be damaged.

- 6 Pick the first CV and slide the CV toward the rear of the model.
- 7 Continue with the rest of the CVs, but decrease the amount of sliding.

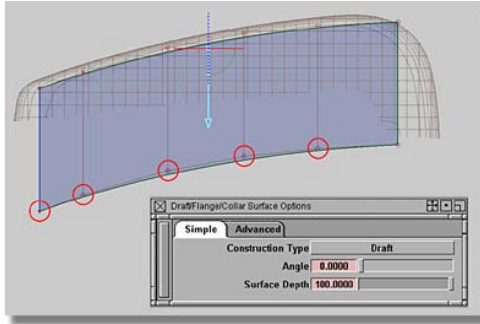



Constructing the Side Surface

The extended theoretical line is the base for the side surface.

Draft the side surface

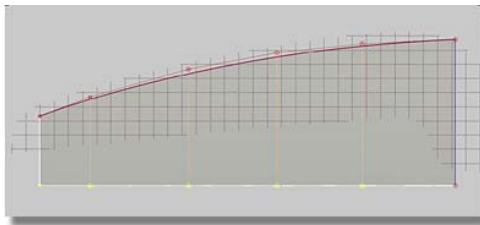
- 1 Create a new layer and name it "Main SRF". The new layer should retain the layer focus.
- 2 Create a draft surface using the theoretical line in the Z-direction. Leave the option box open.
- 3 Move to the side view.
- 4 Increase the length of the draft surface such that the surface covers all of the scan lines.



- 5 Select the new draft surface and turn on the CVs (+).
 - 6 Pick the CVs highlighted in the image above.
 - 7 Choose the **Move** tool from the marking menu.
 - 8 Press **Ctrl** (this will activate Magnetic Snap).
- 
- 9 Use the **right mouse button** to click near to the unselected CV on the right-hand side.



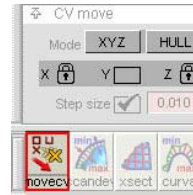
Using the right mouse button will restrict movement to the Z-direction and will allow the selected CV to move onto the desired CV.



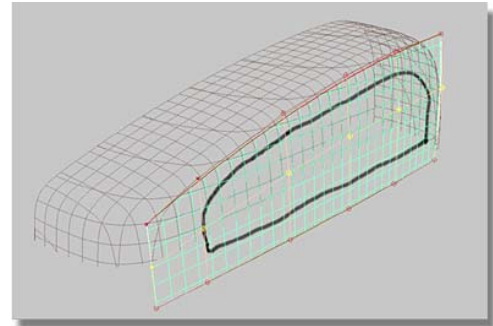
Having produced a surface in the Z-direction, the number of degrees will need to be increased to shape the surface in the Y-direction.

To increase the degree

- 1 In the Control Panel, increase the Degree value from **1** to **2**.
- 2 Tumble the view to a 3D impression.
- 3 Turn on the X-Cross-Section.
- 4 Make sure the Step size value is set to **10**.
- 5 Choose the marked hulls and move them in the Y-direction. Use the **Control Panel > Evaluate > Move CV** tool to lock the X and Z directions (use **HULL** and **XYZ**).



- 6 Fit the side surface to the scan lines by moving the hulls.



In the above image, the marked area denotes the area where the surface will fit to the scan lines. The marked area can be determined by examining the previously fitted curves. The overall surface must have a good CV distribution. As for the marked area, the surface must fit to the scan lines. It is a possibility that three hulls are not enough, in which case, the degree should be increased to **3**. Also, at this stage in the development of the model, avoid moving single CVs as the surface could be damaged. Upon reaching the point where the model cannot be improved, switch the type of surface to gain more flexibility. But first, copy the edges of your current surface to create a square.

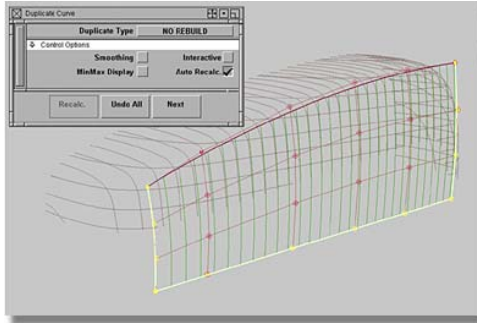
To change the type of surface

- 1 Double-click the **Curve Edit > Create > Duplicate curve** tool to produce the option box.
- 2 Set the options as follows.

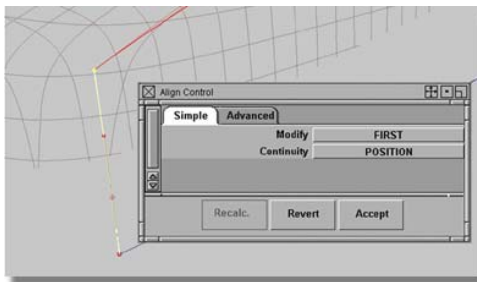


Set this parameter...	To this value
Duplicate type	No rebuild
Smoothing	off
Interactive	off
MinMax display	off
Auto Recalc	on

- 3 Select the edges highlighted in the image below.
- 4 Press the **Go** button.



- 5 Delete the surface.
- 6 Align the small curves onto the bigger ones using the Align tool.
- 7 Set the Align Control options as shown in the image below.



To create a square surface

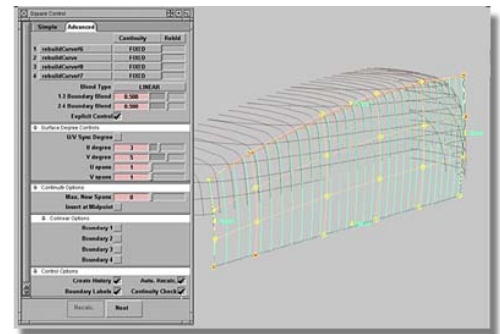


- 1 To build a surface from the four curves, double-click the **Surfaces > Boundary Surfaces > Square** tool.
- 2 Set the Advanced tab options as follows.

Set this parameter...	To this value
rebuildCurves	set all to FIXED Continuity, no Rebuild
Blend Type	LINEAR
1-3 Boundary Blend	0.500
2-4 Boundary Blend	0.500
Explicit Control	on
U/V Sync Degree	off
U degree	3

Set this parameter...	To this value
V degree	5
U spans	1
V spans	1
Max. New Spans	0
Insert at Midpoint	off
Colinear options for boundaries	Set all off
Create History	on
Auto. Recalc	on
Boundary Labels	on
Continuity Check	on

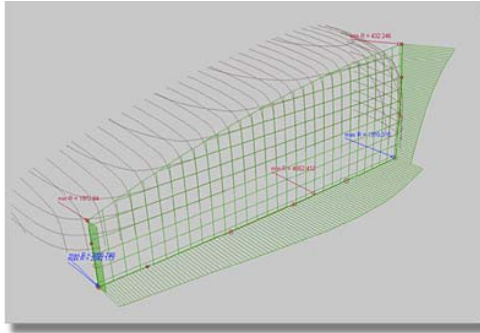
- 3 Pick the four curves in a clockwise direction.
- 4 In the Control Panel, turn on the X-Cross-Section (+).



- 5 In order to see just the CVs that belong to the curves, turn off the CVs of the square (-).
- 6 For the best fit between the square and the scan lines, move the CVs of the curves (mainly in the Y-direction).



While moving the CVs remember to maintain an even distribution of CVs across the curves. Use the Locator tools to monitor the curvature of the curves – try to avoid inflections in the curvature.



After the recent modifications to the model, the theoretical line may need to be adjusted. If adjustments to the theoretical model are required, use the **Curve Edit > Curve planarize** tool to force the theoretical line to adhere to the plane. As for the square surface, the primary requirement is that it fit to the marked area of the scan lines.

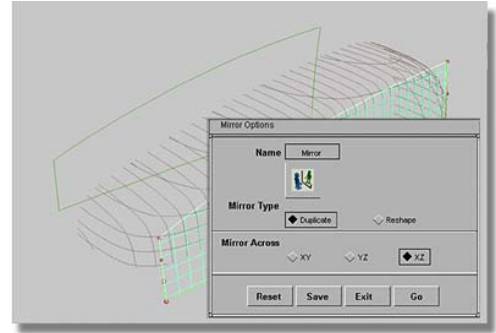


To duplicate the square

- 1 Double-click the **Edit > Duplicate > Mirror** tool to produce the mirror options box.
- 2 Set the mirror options as follows.

Set this parameter...	To this value
Mirror Type	Duplicate
Mirror Across	XZ

- 3 Press the **Go** button.



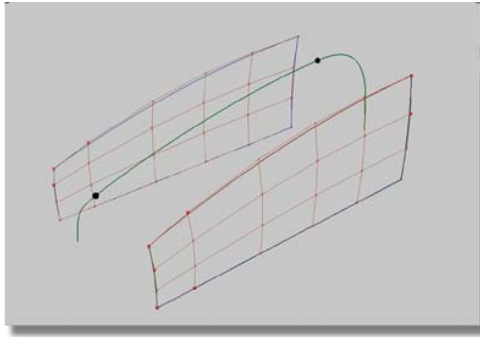
The model now has two side surfaces, but they are not identical. The original side surface has a construction history while the mirrored surface does not. To correct this imbalance, delete the curves used to build the original square – the curves hold the construction history. When the side surfaces are identical (without history), they are complete for this section of the tutorial.

After deleting the curves, the only possibility to model both side surfaces is to use the direct modeling method. You will use the same techniques that were applied to the model when you used curves to modify the square surface. Remember, when applied to two symmetrical surfaces, the direct modeling method requires that corresponding CVs will have to be selected, movement in the X and Z directions must be driven from the **Control Panel > Evaluate > Move CV** tool, and movement in the Y-direction must be conducted using the non-proportional scale. In repeating techniques, you not only gain more experience but may also find new methods to complete the task.

Having completed the two side surfaces, the next step will be to complete the top surface.

Constructing the Top Surface

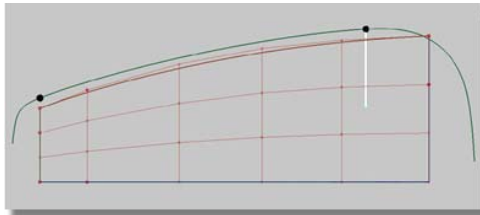
Arrange your screen as shown in the image below. Only the two side surfaces and the center line should be visible.



In the previous section, you created the side surfaces of the body to fit the length of the top surface and to be in line with the center line. In the image below, the small spheres denote the front and rear points of the top curve. As well, the image below clearly shows that the rear of the top curve has no clear connection to the side surfaces of the body.

To connect the rear of the top curve to the side surfaces of the model

- 1 Using the **Viewing Panel**, move into the side view.
- 2 Make sure that the Perspective mode in the **Viewing Panel** does not contain a check mark.
- 3 Starting at the rear point of the top curve of the center line, create a curve that runs in the Z-direction.



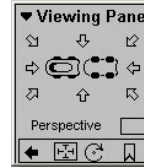
- 4 Select both side surfaces.
- 5 Make sure that you are still in the side view.
- 6 Using the **Surface Edit > Create CurvesOnSurface > Project** tool, project the created curve onto the selected surfaces.



The **Surface Edit > Create CurvesOnSurface > Project** tool always projects the curve onto the selected surfaces in the direction of the current view. Working in the orthographic window while using the **Surface Edit > Create CurvesOnSurface > Project** tool requires some special considerations.

Using the Project tool in the orthographic window

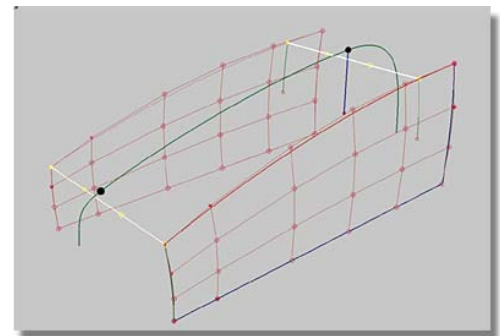
- When executing an operation that requires a direction, make sure that the Perspective option in the **Viewing Panel** is not check marked.



- Before projecting a curve, make sure that you are in a main view (the side, top, or front). To ensure that you are in the appropriate view, choose the corresponding arrow in the **Viewing Panel**. Do not rely on the black colored arrows in the **Viewing Panel**, as they do not show that you are still in the marked view. To be safe, choose the appropriate arrow before projecting.

To build the foundations of the top surface

- 1 Create a degree 3 edit point curve between the surface corners as shown in the image below.
- 2 Create a degree 3 edit point curve between the two Curve on Surfaces as shown in the image below.



Examine the top curve created in the “Fitting curves to X-scans” section. For the top portion of the curve, note that a degree 4 curve was used. To achieve the same results with the current curve, increase the Degree values for both of the newly created curves.

- 3 Select the first curve.
- 4 Turn on the CVs (+).
- 5 In the Control Panel, increase the Degree value to 4.



- 6 Select the second curve and repeat Steps 4 and 5.
- 7 Align the completed curves by position to the corner points of the side surface and to the two Curve on Surfaces. In doing so, the construction history of the curves will be updated to ensure contact with the side surfaces at all times. The construction history option of the Align tool should be turned on.

Reshape both curves by employing the same methods used to fit curves to the X-scans.

Basic rules for modeling the CVs of curves across the Y0 plane

- Select the CVs you need to model, as well as their corresponding CVs.
- Center the pivot point and use the non-proportional scale when modeling across the Y0 plane.
- If modeling in the X and Z directions, use the **Control Panel > Evaluate > Move CV** tool.



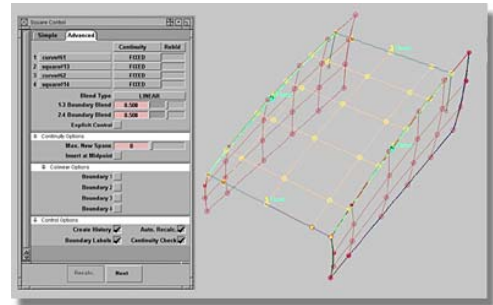
To create a square surface

- 1 Double-click the **Surfaces > Boundary Surfaces > Square** tool to produce the options box.
- 2 Set the options as follows.

Set this parameter...	To this value
Curves	set all to FIXED Continuity, no Rebuild
Blend Type	LINEAR
1-3 Boundary Blend	0.500
2-4 Boundary Blend	0.500
Explicit Control	off
Max. New Spans	0
Insert at Midpoint	off
Colinear options for boundaries	Set all off
Create History	on
Auto. Recalc	on

Set this parameter...	To this value
Boundary Labels	on
Continuity Check	on

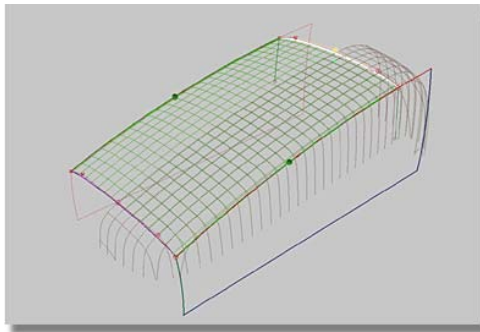
- 3 Construct a square surface using the two curves and both side surfaces.



The newly created surface should be flat and match the length of the top curve of the center line. The next step in the process will be to shape the top surface to fit the scan lines. Because the top surface has a square history, modify the curves on the front and rear of the surface. Once the square surface is updated, check the shape of the surface and compare the results to the scan lines by turning on the cross-sections in the X and Y directions.

To reshape a square surface

- 1 Turn off the CVs of the square surface (-).
- 2 Make sure the CVs of the curves are turned on (+).
- 3 Select the square surface and turn on the X-Cross-Sections and the Y-Cross-Sections.
- 4 Make sure that the Step size value is set to **10** in the cross-section portion of the Control Panel.
- 5 Make the scan lines of the X-scans layer and Y-scans layer are both set to **Visible** and **Set state > Reference**.
- 6 Modify the CVs of both curves to fit the square surface on the scan lines. (Move the CVs in the Z-direction, using the **Control Panel > Evaluate > Move CV** tool).



When fitting the top surface to the scan lines, it may not be clear as to where the surface has to deviate from the scan lines. To help define the area where the top surface has to fit the scan lines, use the X-curves created in the “Fitting curves to X-scans” section. Remember that the scan lines represent the finished model, including the fillets. At this point in the modeling process though, the theoretical model does not include fillets. Using the dimensions of the X-curves, you can determine the location of the fillets and where the top surface needs to fit the scan lines.

After obtaining an acceptable level of deviation to the scan lines, create the fillets to see if the surfaces are located in the right position. At this point in the modeling procedure, the fillets serve as an evaluation tool to help determine if the main surfaces are correct.

If the resulting fillets are not correct, the main surfaces and theoretical line can be further manipulated to achieve the desired results.



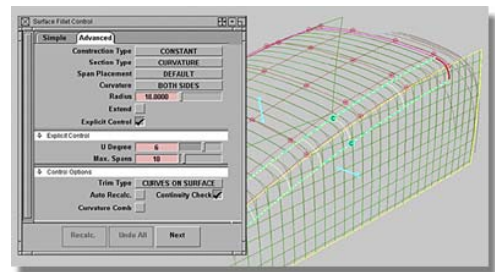
To create a fillet between two surfaces

- 1 Double-click the **Surfaces > Surface fillet** tool to produce the option box.
- 2 Set the options as follows..

Set this parameter...	To this value
Construction Type	CONSTANT
Section Type	CURVATURE
Span Placement	DEFAULT
Curvature	BOTH SIDES
Radius	18
Extend	off

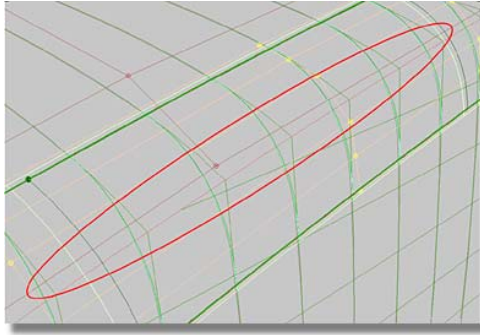
Set this parameter...	To this value
Explicit Control	on
U Degree	6
Max. Spans	10
Trip Type	CURVES ON SURFACE
Auto Recalc.	off
Continuity check	on
Curvature Comb	off

- 3 Select the top surface.
- 4 A blue arrow points in the direction of the current normal of the surface. Click the arrow to make sure it is pointing inwards.
- 5 Press the **Accept** button at the bottom of the screen.
- 6 Select the original side surface and repeat Steps 4 and 5.



- 7 Choose **Pick > Nothing**.
- 8 Select the fillet surface.
- 9 Turn on the X-Cross-Sections to compare the fillet surface with the X-scan lines.

If the main surfaces have an acceptable fit to the scan lines, the fillet surfaces should also fit to the scan lines. If the radius is unknown, experiment with the Radius option value. The objective is to find a solution that allows the fillet entry lines to obtain a close proximity to the endpoints of the blend curve that represents the connection between the top and side of the X-scan line.



In the image above, the area has been marked where the fillet surface does not have an acceptable proximity to the scan lines. To correct the fillet surface, begin by examining both the top and the side surfaces. If either of the surfaces is found to be in error, corrections will have to be conducted. To reduce confusion in the view and speed-up the modification process, make the fillet surfaces invisible.

Factors to consider when making corrections to surfaces

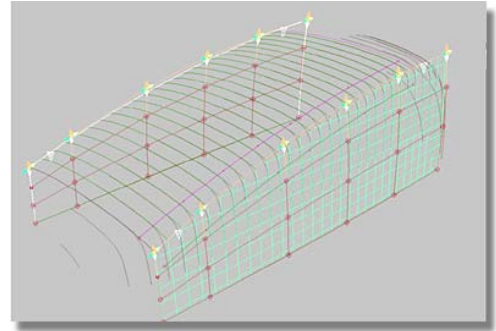
- When modifying a side surface, remember that there are two side surfaces. To maintain the symmetrical character of both side surfaces, corresponding CVs must be selected for movement and modification.
- When modifying the top surface, keep in mind that the top surface runs across the Y0 plane, and as a result, there are special modification requirements for the movement and modification of CVs.
- It is important to remember to maintain the planar character of the theoretical line. The safest course of action is to move the hulls (not single CVs) that represent the theoretical line.

To change the theoretical line by moving hulls

- 1 Select the fillet surface.
- 2 Choose **ObjectDisplay > Invisible** from the menu.
- 3 Turn on the CVs of both side surfaces.
- 4 Select the upper hull of both surfaces.
- 5 Choose the **Transform > Local > Center pivot** tool.
- 6 Move both hulls using the non-proportional scale.



- 7 Choose **Pick > Nothing**.
- 8 Select both hulls again.
- 9 Choose the **Control Panel > Evaluate > Move CV** tool and slide both hulls in a downward direction. This procedure should require only a small degree of movement.
- 10 Choose **ObjectDisplay > Visible** from the menu to make the fillet visible again.



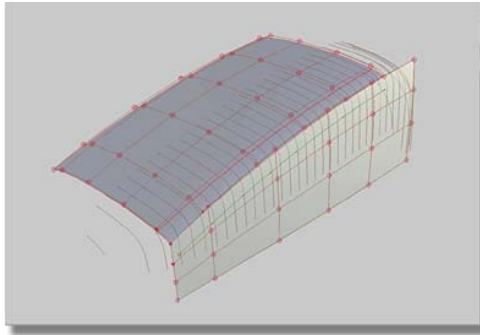
To save your work

- 1 Create a new layer and name it "my main srf".
- 2 Select the newly created side surfaces, the top surface, and the fillet surface.
- 3 Assign the selected surfaces to the "my main srf" layer.
- 4 Save your work.

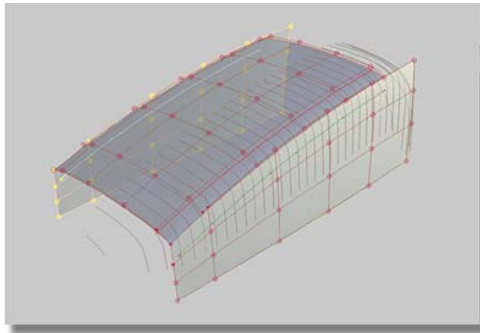
To construct a new construction history using the Align tool

If the construction history of the top surface is lost, the connection to the side surfaces will also be lost. To rebuild the construction history of the top surface, a new modeling strategy will be introduced to achieve the desired results. You can also use this strategy if you lose the symmetrical character of the side surfaces.

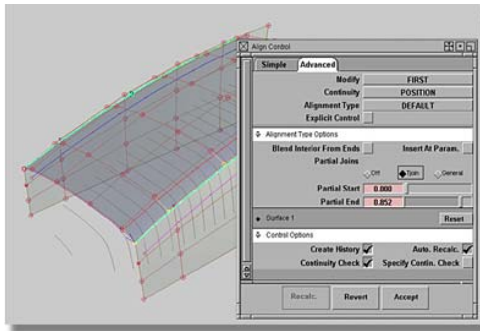
- Delete the mirrored surface to make sure you have just the original side surface.



- Mirror the side surface to ensure that both side surfaces are identical.



- In the Alignment Type Option tab found in the Align Control box, set the **Partial Joins** option to Tjoin. Align the top surface by position to the first side surface. Repeat the procedure on the other side.

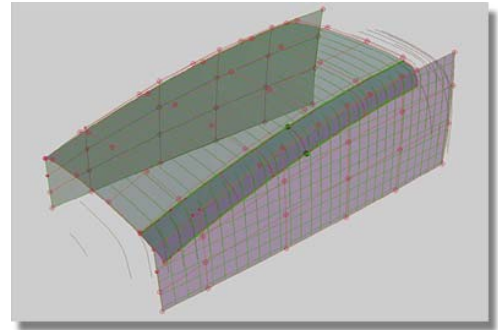


If the planar characteristics of the theoretical line have been lost due to the accidental movement of a single CV, use the **Curve Edit > Curve planarize** tool to re-establish the characteristics. The **Curve Edit > Curve planarize** tool can be employed on curves as



well as surface edges, such as the theoretical line. When using the **Curve Edit > Curve planarize** tool, set the Default Projection Plane to Best, and turn off the Keep Originals option. Repeat the planarize process for the other side surface.

If all of the procedures of this section were successfully executed, your model should resemble the image below.



Summary

- By creating fillets, you can ensure that the main surfaces are correct.
- Fillets may result in surface errors that can only be corrected by adjusting the main surfaces.

- If the history of a surface is lost, use direct modeling and the **Object Edit > Align > Align** tool to create a new construction history.

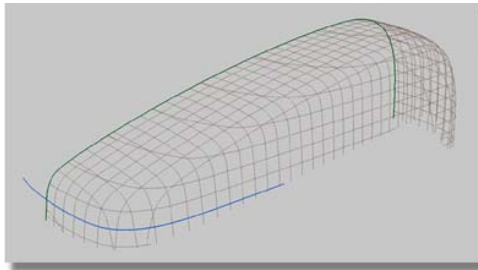


To continue building the main surfaces, you will use some of the previously fitted curves to construct the front and rear surfaces.

Applying a Transition Between the Front and Top Surfaces

To use the Rail tool

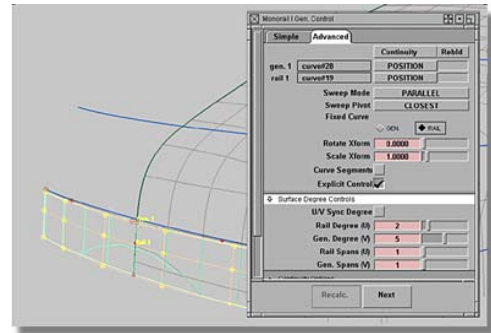
- 1 Arrange your screen as shown in the image below. Only the X, Y, and Z scan lines, the center line, and certain Z-curves should be visible.



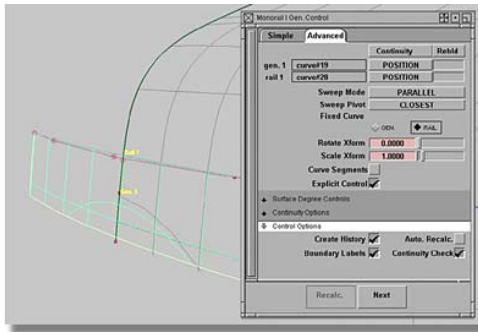
- 2 Double-click the **Surfaces > Swept surfaces > Rail surface** tool to produce the option box.
- 3 Because there are only two curves to create the surface, use 1 Generation curve and 1 Rail curve. Pick the Z-curve first to mark it as the Generation curve.
- 4 Select the portion of the center line you need to create the front surface.
- 5 Set the Rail options as shown..

Set this parameter...	To this value
gen.1 (curve #28)	Continuity set to Position, Reblid off
rail 1 (curve #19)	Continuity set to Position, Reblid off
Sweep Mode	PARALLEL
Sweep Pivot	CLOSEST
Fixed Curve	RAIL
Rotate Xform	0.0000

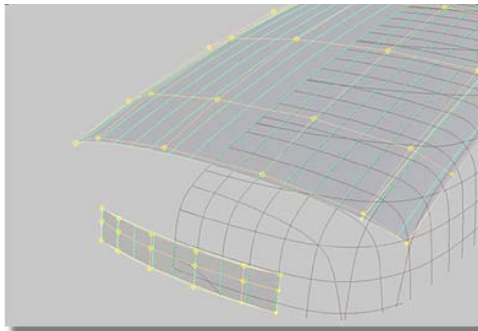
Set this parameter...	To this value
Scale Xform	1.0000
Curve Segments	off
Explicit Control	on
U/VSync Degree	off
Rail Degree (U)	2
Gen. Degree (V)	5
Rail SPans (U)	1
Gen Spans (V)	1



- 6 Repeat Steps 3 and 4 to create another surface, but reverse the selection order. The new surface differs from the original because of the selection order of the Generation curve and Rail curve.



- 7 Hide the curves and make the top surface visible.

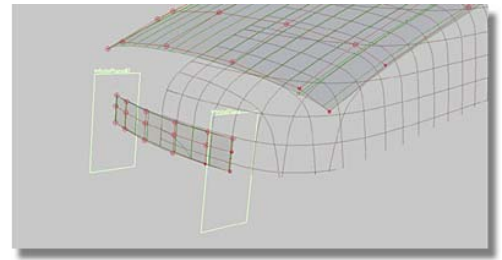


A new method utilizing construction planes will be introduced to build the transition surface.



To use a construction plane

- 1 Choose the **Construction > Plane** tool. A 3-point plane will be created.
- 2 Using CRV snapping (press **Ctrl + Alt**), select a corner point of the front surface to mark the centre of the new construction plane.
- 3 Using CRV snapping, select the opposite corner point of the front surface to mark the X-axis point of the new construction plane.
- 4 Using CRV snapping, select a point between the two points already selected. The third point defines the plane. Make sure that the third selected point is snapped to the edge of the front surface.
- 5 Repeat Steps 3 and 4 for the other edge of the front surface.

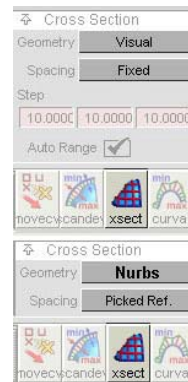


If a construction plane is created using geometry (3-point plane, surface plane), the construction plane will always have an associated construction history. Deleting the geometry used to create the construction plane will also delete the construction plane, even if the construction plane is assigned to another layer. If you want to delete the geometry but maintain the construction plane, delete the construction history of the construction plane to achieve independence. If a number of construction planes are required for the modeling process, each construction plane can be named using the **Windows > Information > Information window** menu item.

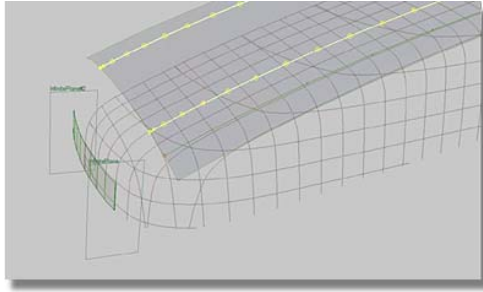
To intersect a construction plane with a surface

- 1 Select both construction planes and the top surface.
- 2 Double-click the **Control Panel > Evaluate > Cross-section** tool to produce the options box.
- 3 Set the options as shown in the images below.

Changing the **Geometry** option to **NURBS** will create Nurbs curves on the reference surface. The Nurbs curves have a poor CV distribution, but offer a connection history to the construction plane.



At this point in the process, your model should resemble the image below.



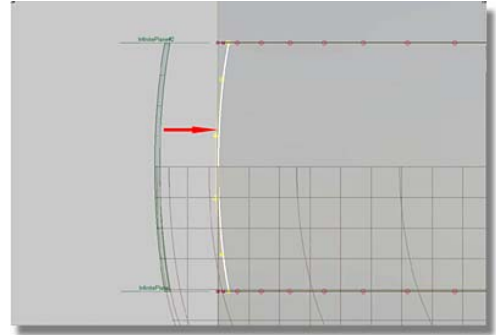
Before proceeding, it should be noted that the straight edge of the top surface could not be used to construct the transition surface. In the top view, the front surface displays a curved character that must flow through to the top surface. In order to transition the curved character of the front surface, apply a curve-on-surface shaped similar to the front surface.

To change the shape of an edge by trimming the basic surface

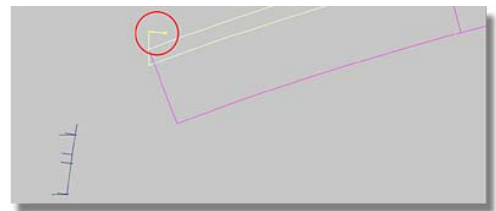
- 1 Duplicate the edge of the front surface to produce a curve. (Use the **Curve Edit > Create > Duplicate curve** tool).
- 2 Move the duplicated curve in the X-direction so that the curve fully covers the top surface.
- 3 Switch into the top view using the **Viewing Panel**.
- 4 Project the moved curve onto the top surface. The model now has a curve-on-surface that defines the edge of the transition surface to be built later in the tutorial.



To get a better view of the problem hide both intersection curves as shown in the image below.

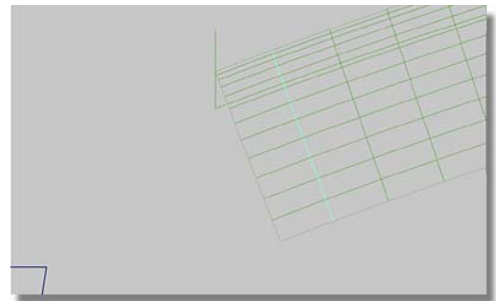


From the top view, the curve-on-surface appears to be acceptable, but in the side view, the curve-on-surface does not follow the isoparametric directions of the fillet surface.

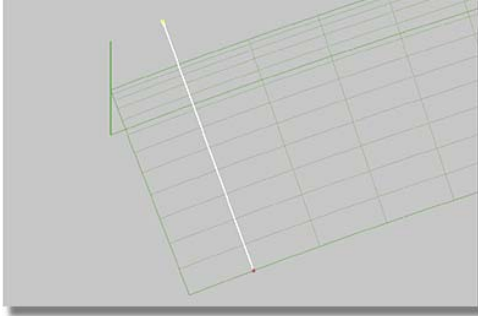


The imbalance between the curve-on-surface and the fillet surface may produce difficulties during the process of balling the corners. To minimize the difficulties associated with balling the corners, reshape the curve-on-surface along the isoperimetric line of the fillet surface.

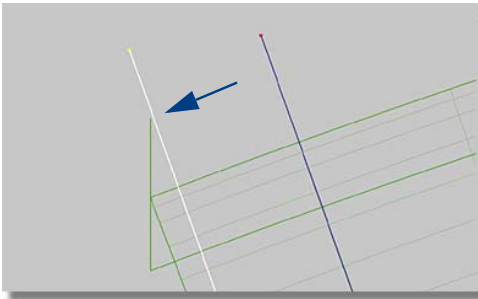
- 5 Go into the side view.
- 6 Select the fillet surfaces.
- 7 Choose the **Object edit > Patch precision** tool. Press the **left mouse button** and slide it horizontally to the right until the isoperimetric lines resemble the image below.
- 8 Create a degree 1 edit point curve along the isoparametric line highlighted in the image below.



- Pick the endpoint of the duplicated curve and slide the CV upwards to point beyond the top surface.



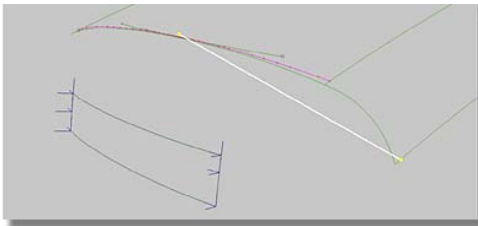
- Move the curve in the X-direction to the front edge of the top surface.



- Make sure that you are still in the side view and project the curve onto the side surface.

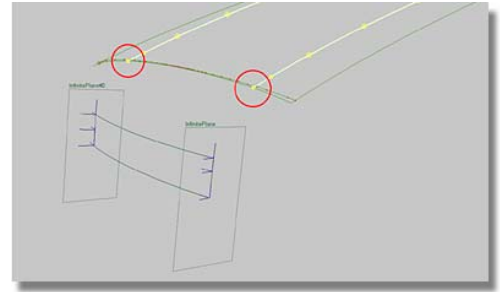


- Return to the **Object edit > Patch precision** tool and select the fillet surface, press the **left mouse button**, and slide the mouse horizontally in the left direction to remove all of the isoperimetric lines. You can also type a **2** into the Prompt line to achieve the same results.



A new curve-on-surface is created that differs from the original straight edge of the top surface and has a better appearance in the side view.

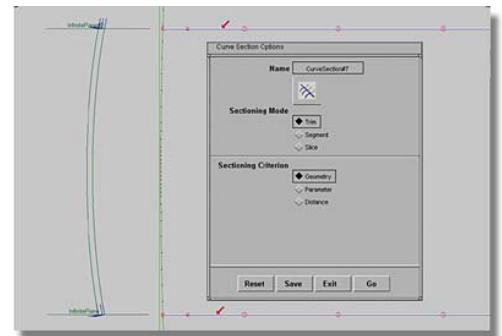
- Delete the original curve-on-surface.



Both of the curves built by intersecting the construction plane with the top surface are too long and must be cut to match the curve-on-surface.

To cut a curve using reference geometry

- Switch to the top view.
- Double-click the **Curve Edit > Curve section** tool to open the option box.
- Select both intersection curves as shown in the image below.
- Press the **Go** button at the bottom of the screen to complete the selection process.
- Select the curve-on-surface as a reference for cutting the selected curves.

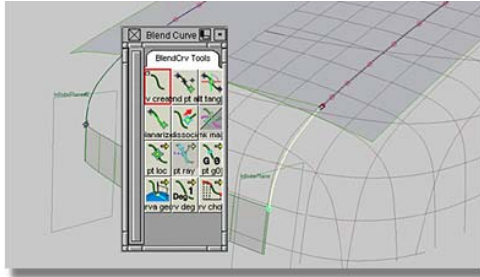


Before using the Rail tool, define two blend curves between the intersection curves and the front surface.

To use blend curves to define the edges of transitional surfaces

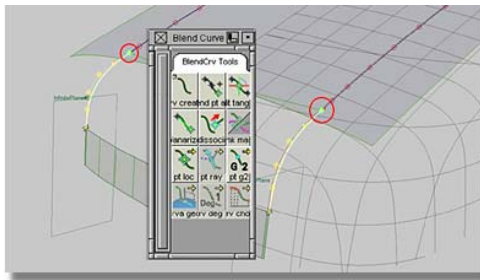
- Create two blend curves that resemble the image below.
- In the Blend Curve option box, choose the **BlendCrV Tools > Blend curve create** tool and select the curves and the edges using CRV snapping (press **Ctrl + Alt**).





By connecting a blend curve with a curve, the blend curve does not contain the curvature required for the model. As a general rule, a blend curve connected to a curve will always contain **POSITION Continuity G0**. (Remember the previously completed curve-fitting section).

- 3 Select both blend points that connect to the curves.
- 4 Choose the **Go** button, hold down the mouse, and move until you arrive at **G2**.
- 5 Release the mouse button. The blend curves will project from the curves by a curvature value of **G2**.



To use the Rail tool to create the transition surface

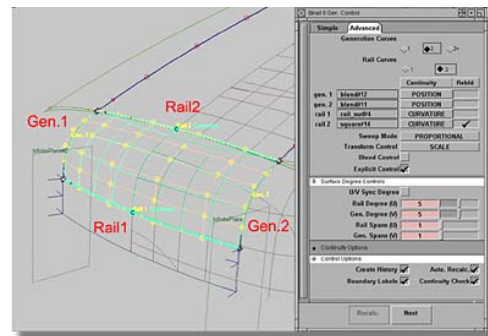


- 1 Double-click the **Surfaces > Swept surfaces > Rail surface** tool to open the option box.
- 2 Set the options as follows..

Set this parameter...	To this value
Generation Curves	2
Rail Curves	2
gen. 1 (blend#12)	Set Continuity to POSITION, Reblid off

Set this parameter...	To this value
gen. 2 (blend#11)	Set Continuity to POSITION, Reblid off
rail 1 (rail_surf#4)	Set Continuity to CURVATURE, Reblid off
rail 2 (square#14)	Set Continuity to CURVATURE, Reblid on
Sweep Mode	PROPORTIONAL
Transform Control	SCALE
Blend Control	off
Explicit Control	on
U/V Sync Degree	off
Rail Degree (U)	5
Gen. Degree (V)	5
Rail Spans (U)	1
Gen. Spans (V)	1
Create History	on
Auto. Recalc.	on
Boundary Labels	on
Continuity Check	on

- 3 Select both blend curves, then, select the curve-on-surface and the edge of the front surface.



Activate the X-Cross-Sections of the new Rail surface. The updated Rail surface does not fit to the scan lines because the blend curves are flawed. To correct the problem, modify the blend curves at the same time to maintain the model's symmetry.

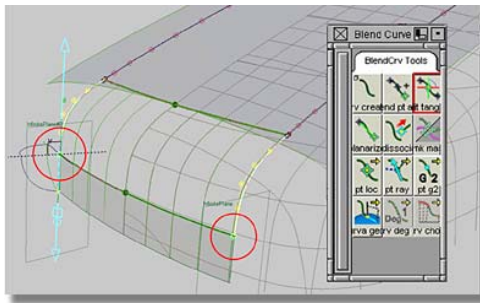
To modify the blend curves

- 1 Select the two opposing blend points.
- 2 Choose the **BlendCrv Tools > Blend curve edit** tool.

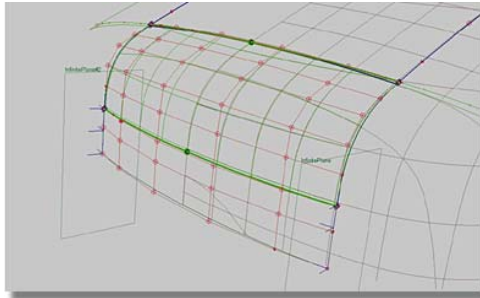


The **BlendCrv Tools > Blend curve edit** tool will produce a single Locator that will be responsible for both selected blend points.

- 3 Select the blue square of the Locator, hold down the mouse button and move it until the desired results are achieved.
- 4 Try the same procedure with the blue sphere.
- 5 If the blend curves are moved correctly, the Rail surface will update to fit the scan lines.

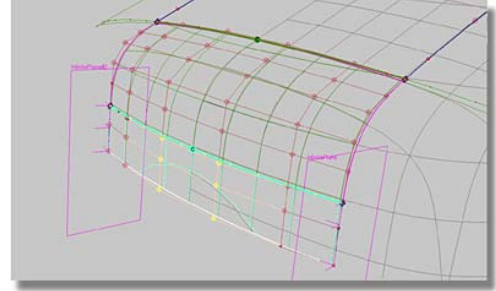


If the modification of the blend curve did not achieve the desired fit to the scan lines, examine the front and top surfaces to determine if further changes are required.



When modifying the front surface, use the direct modeling method (moving the CVs of the front surface). One of the consequences of modifying the front surface using direct modeling is that the construction history of the Rail surface will be lost. As well, because the front surface runs across the plane at the Y0 position, the symmetry will need to

be maintained. (Keep in mind the rules for modifying CVs that run across the Y0 plane).



When modifying the top surface, remember that the top surface has a construction history that ties it to the fillet and side surfaces. As a result, modification of the top surface will be a time-consuming endeavour because the fillet surface will also have to be updated. To speed-up the modification process, postpone the recalculations by temporarily suspending the construction history. When you have found an acceptable modification, reinstate the construction history. Another restriction against modifying the top surface is that the edge of the top surface connects to the side surface, and as such, cannot be modified because the side surfaces are the references for the top surface.

How to suspend calculations

- 1 Choose the **H** to the right of the Prompt line (above the layer bar).
- 2 Hold down the **H** button until a menu appears.



- 3 Move the cursor over **Suspend Rebuilds** and release.



A diagonal line should now cut through the **H**.

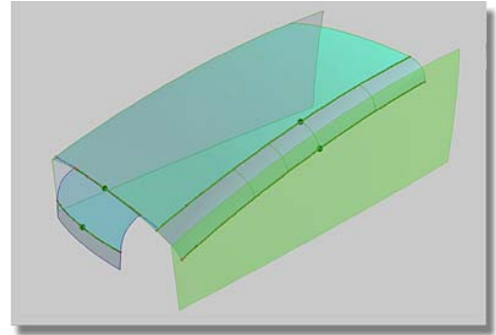


How to reactivate the calculation

- 1 Press the **H** button.
- 2 Hold down the mouse button and move the cursor over **Suspend Rebuilds**.
- 3 Release the mouse.



After finishing the front surface and the transition to the top surface, your model should resemble the image below.



> Summary

- Projecting curves to create new edges may require a number of attempts to achieve the desired results.
- Projecting curves to create new edges will require extra attention because they are instrumental in producing a useful Patch Layout.
- Curve on Surfaces should be evaluated from a variety of views in order to find the best shape.

Applying a Transition Between the Rear and Top Surfaces

The rear surface will be constructed using a similar approach to that used in creating the front surface. A Rail surface will be constructed using two curves from the center line and a corresponding Z- curve.

To create the transition surface, you will use the fillet surfaces already created, but there will be no need to create construction planes or curves that intersect with the top surface.

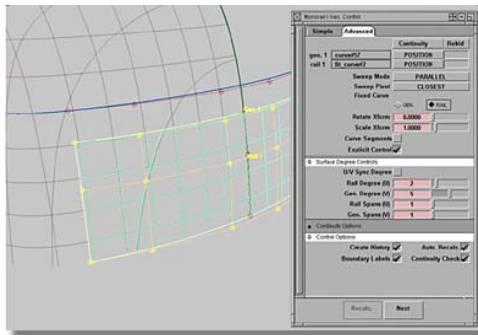
Given the shape of the rear scan lines, the edge of the transition surface will be shaped to touch the top surface using a curve-on-surface.

To create the Rail surface

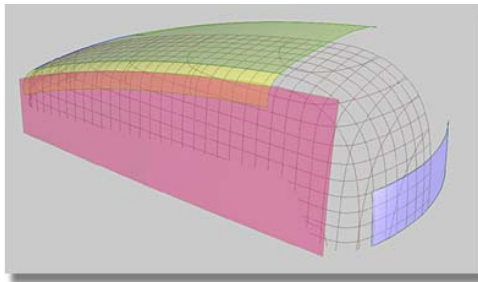
- 1 Create a Rail surface using 1 Generating curve (Z-curve) and 1 Rail curve (part of the center line).
- 2 Set the options as follows..

Set this parameter...	To this value
gen.1 (curve#57)	Set Continuity to POSITION and Reblid off
rail 1 (fit_curve#2)	Set Continuity to POSITION and Reblid off
Sweep Mode	PARALLEL
Sweep Pivot	CLOSEST
Fixed Curve	RAIL
Rotate Xform	0.0000
Scale Xform	1.0000
Curve Segments	off

Set this parameter...	To this value
Explicit Control	on
Rail Degree (U)	2
Gen. Degree (V)	5
Rail Spans (U)	1
Gen. Spans (V)	1
Create History	on
Auto. Recalc.	on
Boundary Labels	on
Continuity Check	on



- 3 Arrange the scene to offer the best view of the new rear surface, the top surface, the fillet surfaces, the side surfaces, and all of the scan lines.



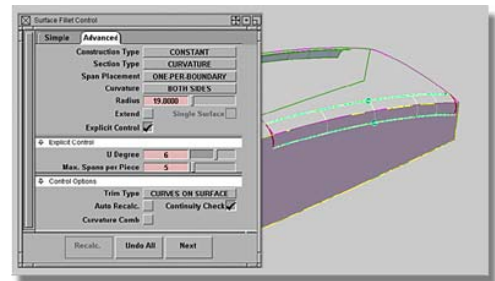
In this section of the modeling process, you will build the transition surface over the Y0 plane and maintain the construction history throughout the entire operation. You will begin the construction by creating a fillet on the other side of the model, but first, examine the options of the existing fillet. In order to produce the options box for the existing fillet, the **Object edit > Query edit** tool can be used



if the construction history of the existing fillet has not been lost.

To use the Query Edit tools

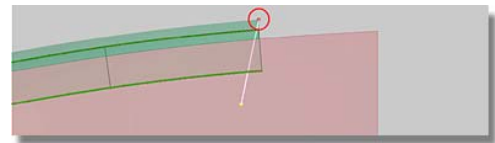
- 1 Select the fillet surface.
- 2 Choose the **Object edit > Query edit** tool.
- 3 Step 2 produces the Surface Fillet Control box. Take note of the arrangement of the options.
- 4 Choose **Pick > Nothing**.
- 5 Using the same options as previously, create a fillet on the other side of the model to achieve identical fillet surfaces on both sides of the model.



Now you are ready to create a curve-on-surface that will be the top edge of the rear transition surface. The curve-on-surface must have the curved character of the rear surface as seen in the top view.

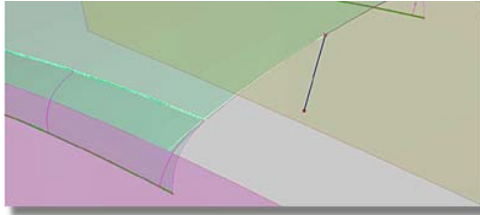
To shape one edge of the rear transition surface

- 1 Use the **Viewing Panel** to switch to the side view.
- 2 Create a degree 1 edit point curve as shown in the image below.



- 3 Remain in the side view and project the curve onto both fillets and the top surface. (Use the **Surface Edit > Create CurvesOnSurface > Project** tool).
- 4 Tumble the view to see the newly created curve-on-surface.
- 5 Select the curve-on-surface.

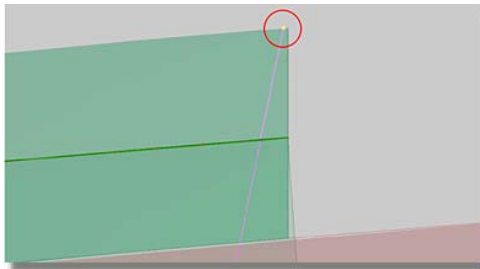




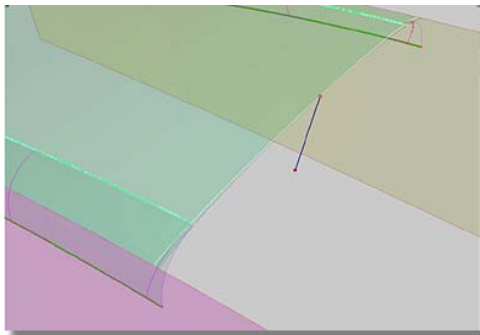
The resulting curve-on-surface could be split into two parts, one of which is highlighted. The entire curve-on-surface is not highlighted because there is a problem with the curve used for the projection.

To correct the curve and complete the curve-on-surface

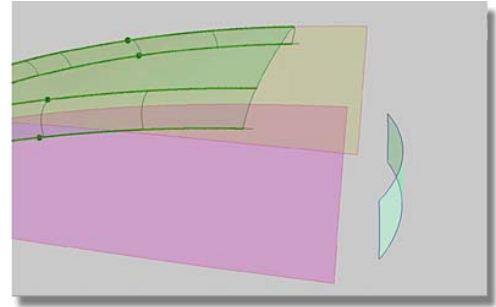
- 1 Return to the side view.
- 2 Select the upper CV of the curve.
- 3 In small increments, move the CV in the X-direction toward the front of the model.



- 4 Tumble the view again and examine the updated curve-on-surface - it should now be one curve-on-surface that extends across the top surface.

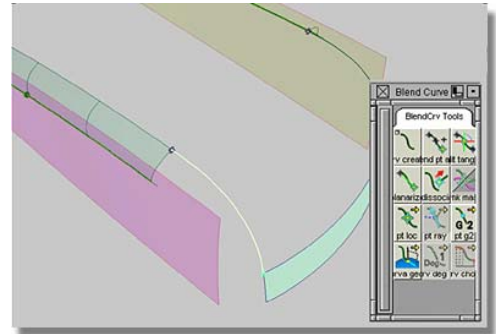


- 5 Create a new layer and name it "work curves".
- 6 Assign the curve you used for the projection to the new layer.
- 7 Make the new layer invisible.
- 8 Trim the top surface and both fillet surfaces.



To create blend curves between the rear surface and the fillets

- 1 Make the top surface invisible. (Use the **ObjectDisplay > Invisible** menu item).
- 2 Choose the **BlendCrV Tools > Blend curve create** tool.
- 3 Create two blend curves between the rear surface and the fillets.



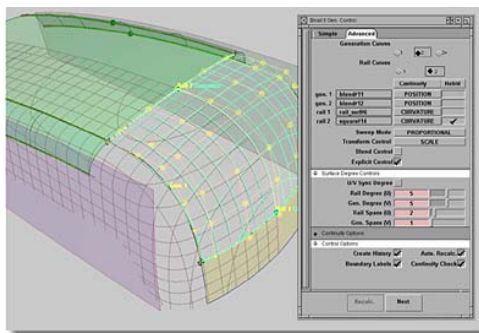
To create a new Rail surface

- 1 Use **ObjectDisplay > Visible** to make the top surface visible.
- 2 Set the options as follows.

Set this parameter...	To this value
Generation Curves	2
Rail Curves	2
gen. 1 (blend#11)	Set Continuity to POSITION, Rebltd to off

Set this parameter...	To this value
gen. 2 (blend#12)	Set Continuity to POSITION, Reblid to off
rail 1 (rail_surf)	Set Continuity to CURVATURE, Reblid to off
Rail 2 (square#14)	Set Continuity to CURVATURE, Reblid to on
Sweep Mode	PROPORTIONAL
Transform Control	SCALE
Blend Control	off
Explicit Control	on
U/V Sync Degree	off
Rail Degree (U)	5
Gen. Degree (V)	5
Rail Spans (U)	2
Gen. Spans (V)	1
Create History	on
Auto. Recalc.	on
Boundary Labels	on
Continuity Check	on

- 3 Create a Rail surface.
- 4 Select both blend curves, then, select the edge of the rear surface and the trimmed edge of the top surface.
- 5 Turn on the X, Y, and Z Cross-Sections for the new Rail surface.



Further adjustments may be required to achieve a better fit between the rear surface and the scan lines. To correct the errors, the Rail surface will have to be adjusted. However, there are a number of strategies that could be employed.

Strategies for adjusting Rail surfaces

- Modify the blend curves
- Modify the rear surface
- Modify the top surface.

The modification of the Rail surface will require the employment of all three methods. Before starting the modifications, consider the following factors that could determine the proper course of action.

Factors to consider when adjusting Rail surfaces

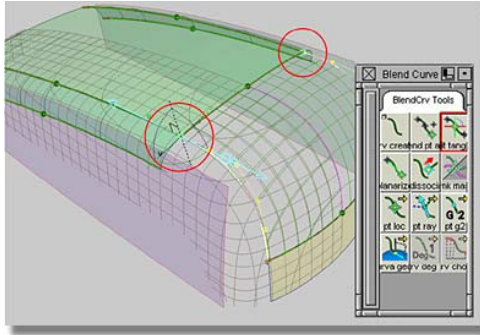
- The modification of blend curves is relatively easy due to the availability of a manipulator to conduct the changes.
- The modification of the rear surface will be more difficult considering the presence of previously balanced curves. To change the curves may involve unnecessary, time-consuming work. (If the Rail surface must be modified, use the direct modeling method).
- The modification of the top surface is also quite difficult because you have to take into consideration that the front transition and the fillets belong to the top surface. What appears on the surface to be an easy modification may in fact have a major impact on the model. Also, the edge of the top surface cannot be modified because the edge belongs to the side surface.

The proper course of action is to begin by modifying the blend curves.

To fit the transition surface by modifying the blend curves

- 1 Select corresponding blend points.
- 2 Choose the **BlendCrv Tools > Blend curve edit** tool.
- 3 A manipulator will appear. Click and hold the blue rectangle, or the blue sphere, and move each manipulator to achieve the best shape for the blend curve.

The blend curve and the transition surface will update to reflect the modifications.



top surface, the associated surfaces will also require recalculations that could result in time delays. To avoid time delays, use the **Windows > Information > History view** menu item to suspend the recalculations during the modification process.

See the section entitled “The transition between the front and top surfaces” for the details concerning the suspension and reactivation of the calculations.

After finishing the modification to the rear transition surface your model should resemble the image below.

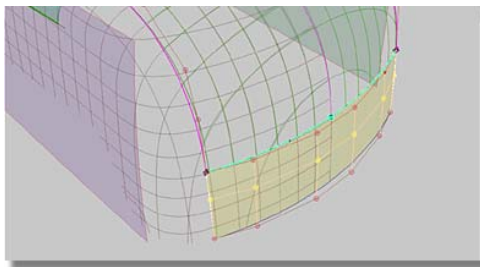
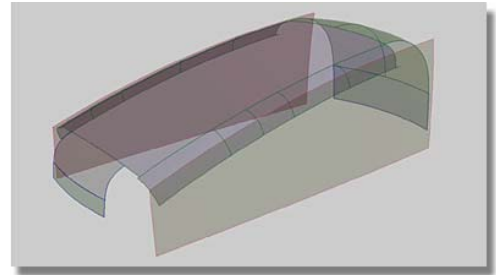
To fit the transition surface by modifying the rear surface

- 1 Turn on the CVs of the rear surface.



You must determine whether or not the transition surface will need to be flat or curved at the area where the rear surface has influence. If you decide that the transition surface has to be flattened, modify the rear surface in the same manner. You can achieve the surface modifications by moving CVs, but keep in mind that because the rear surface crosses the Y0 plane, you must always select the corresponding CVs. As well, when moving CVs in the in Y-direction, you will need to center the pivot before using the non-proportional scale.

- 2 Pick corresponding CVs or hulls and move them in the X-direction.
- 3 Monitor the impact that the CV modifications have on the transition surface.



> To fit the transition surface by modifying the top surface

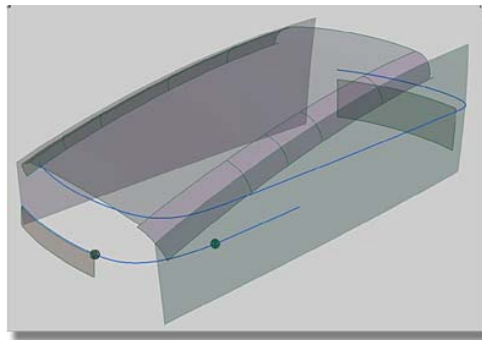
The top surface is related to two fillet surfaces and the front and rear transitions. When modifying the

TRANSITION SURFACES

Constructing Simple Transitions

The next step is to model a transition surface that will connect the front surface with the side surface. To begin, determine where the transition surface starts on the side surface by using the fitted Z-curves. In the image below, the spheres at the endpoints of the curve show where the transition has to be placed on the side surface.

To construct the transition surface at the front



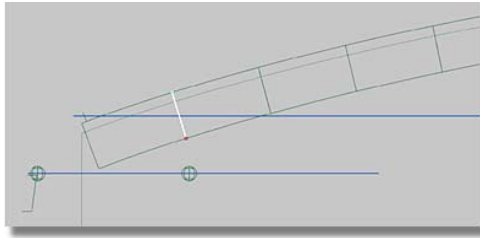
Construct a surface that will connect the front and side surfaces.

- 1 Open the wire file `Transition Surfaces.wire`.
- 2 Select the surfaces from the “work” layer and choose **View > Look at** tool.

Use the surfaces in the “work” layer. Keep the layer highlighted in yellow so that all new geometry will be assigned to the layer.

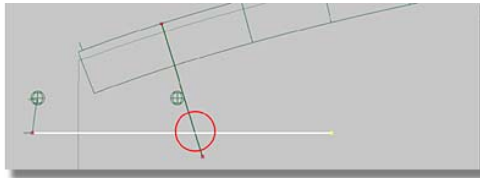
- 3 Use the **Viewing Panel** to switch to the side view.
- 4 Create a degree 1 edit point curve that follows an isoperimetric curve of the fillet.

In the image below, use the right-most ball as a guide to where the curve has to be positioned. Eventually, the curve will have to be moved slightly in the X-direction.

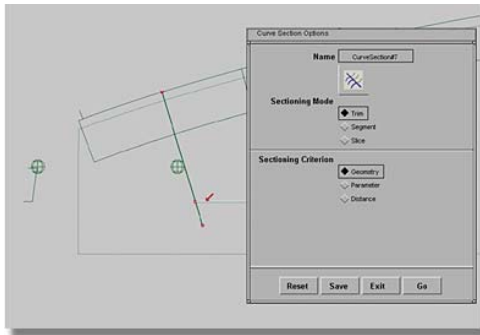


An isoparametric curve is used in this procedure to maintain the natural character of the fillet.

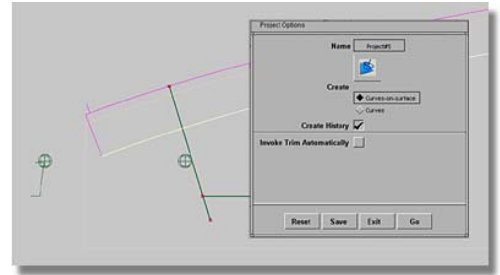
- 5 Select the bottom CV of the curve and slide it down to reach the bottom level of the front surface.
- 6 Create a degree 1 edit point curve following the bottom edge of the front surface. The curve is parallel to the X-direction.
- 7 Make sure the curve is long enough to cross the curve created in Step 2.



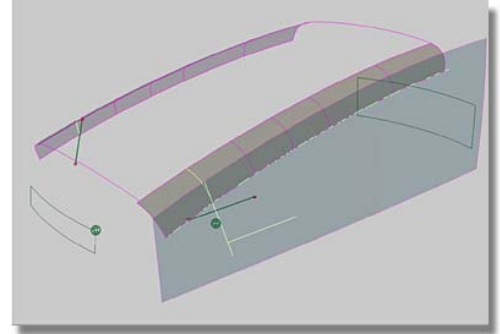
- 8 Cut the curve as shown in the image below.



- 9 Press **Shift + Alt** to produce the **Viewing Panel**. Ensure that the Perspective view has not been activated. Click on the side arrow to make sure you are in the side view.
- 10 Project both curves onto the side surface and onto the fillet surfaces.



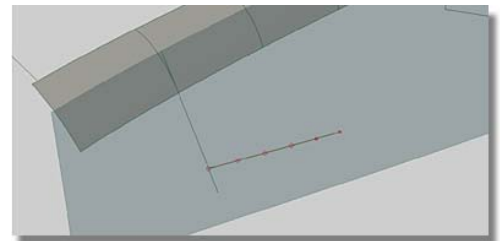
The model should now have a new curve-on-surface that resembles the image below.



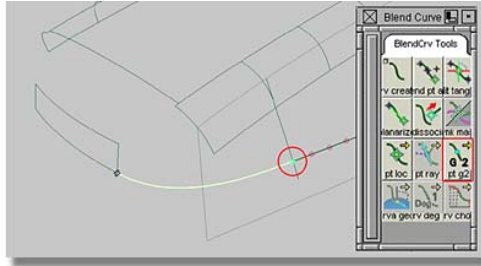
The next step is to define the curves of the transition surfaces by using blend curves.

To create the transition surfaces

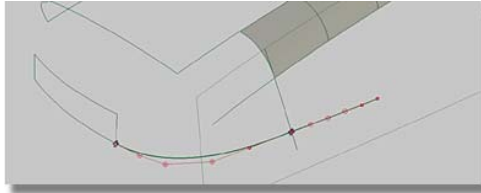
- 1 Double-click the **Curve Edit > Create > Duplicate curve** tool to produce the option box.
- 2 Set the **Duplicate Type** to **NO REBUILD**.
- 3 Pick the curve-on-surface of the side surface.



- 4 Delete the curve-on-surface of the side surface.
- 5 Create a blend curve between the duplicated curve and the front surface.
- 6 Select the blend point that is connected to the curve and change the **Continuity** to **G2**.



- 7 Trim the fillet. Keep the surface similar to the dark gray area in the image below.



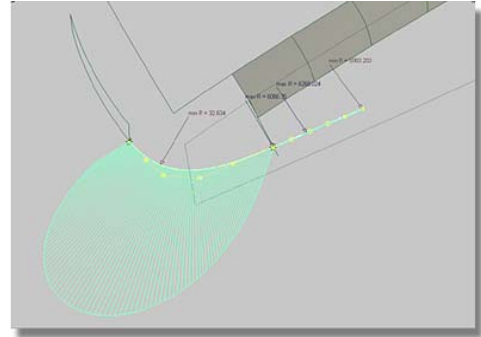
In a previous section, you fitted curves to Z-scan lines. The curves created in that section served as guides for establishing the correct Patch Layout. The curves created in this section are designed to serve as the framework of the surfaces. To ensure that the curves created in this section are correct, check the curvature combs of the curves.

To create and modify a curvature comb

- 1 Select the two curves.
- 2 Calculate a curvature comb over both curves using the **Locators > Curve curvature** tool.
- 3 Use the **middle mouse button** to adjust the density of the curvature comb.



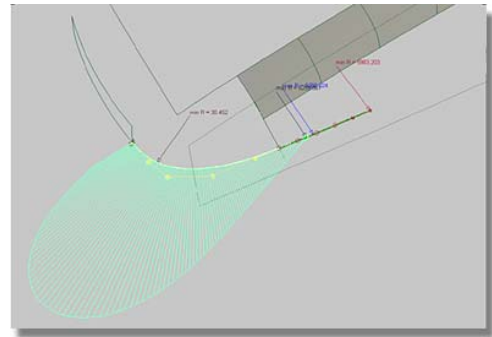
By moving the right mouse button, you can adjust the size of the curvature comb.



If the resulting curvature comb resembles the image above, the comb may have an imbalance caused by the abrupt change between the curvature of the blend curve and the duplicated curve. To correct the curvature comb, manipulate the blend point.

To correct the curvature comb

- 1 Select the blend point and move it by curve snapping (press **Ctrl + Alt**) along the duplicated curve.
- 2 Watch the curvature comb.



Modifying the curvature comb may change the impression you achieved by fitting the Z-scans (the size of the transition surface). However, the side surface has more value when judged as a Z-curve, and as a result, the new modifications should be kept.

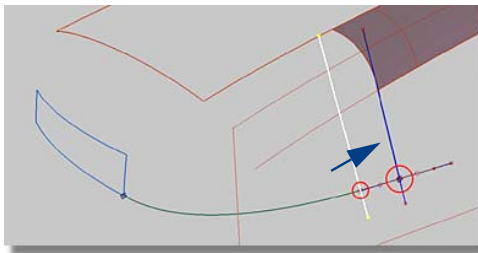
To continue with the modeling process, prepare the model for the next required transitional curve.

The fillet surface was created using the **CURVES ON SURFACE** setting found in the **Trim Type** option of the **Surfaces > Surface Fillet** tool. To avoid confusion when creating the next transitional blend curve, hide the curve-on-surface using the **Object edit > Query edit** tool. The **Object edit > Query edit** tool reproduces the option box, or control box, of the tool you used to create the selected surface. In this case, it is the Surface Fillet Control box. In the control box, change the **Trim Type** to **OFF**.

Because you slid the blend point along the curve associated with the side surface, the trim curve of the fillet surface will also have to be moved.

To snap a curve to a pre-defined point

- 1 Switch to the side view.
- 2 Make visible the curve previously used to trim the fillet surface.
- 3 Set the pivot point at the lower end of the curve.
- 4 Move the curve to the new position of the blend point, marked in the image below with a large sphere.
- 5 To find the exact position use the Magnetic Snap (press **Ctrl** and click close to the blend point).



This will change the curve-on-surface on the side surface as well as the curve-on-surface of the fillet surface. The next step will be to create the other transitional curve that will become the foundation for the transitional surface between the side surface and the front surface.

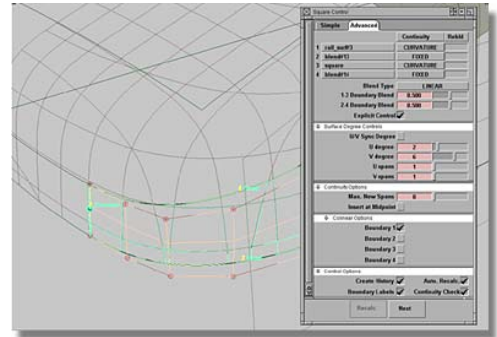
But before creating the transitional curve, hide the curve-on-surface on the side surface by using the **Object edit > Query edit** tool.

To use Query Edit to hide the curve-on-surface



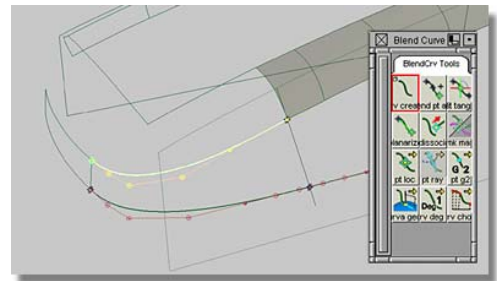
- 1 Choose the **Object edit > Query edit** tool.
- 2 Pick the edge of the fillet surface. The option box will appear.

- 3 Set the **Trim Type** to **OFF**.
- 4 If the recalculate option is turned off, press **Recalc** at the bottom of the options box.

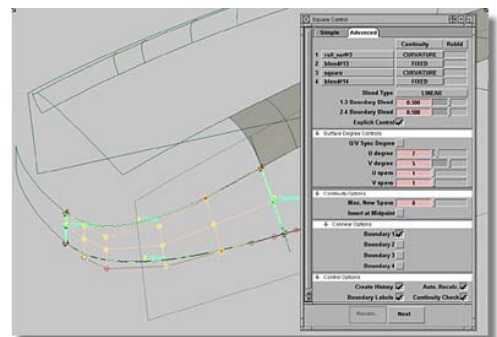


To add a square surface

- 1 Create a blend curve between the fillet surface and the front surface. Because you hid the curve-on-surface, the fillet surface can be selected without clutter.



- 2 Set the options of the square surface as shown in the options displayed in the image below.
- 3 Turn on the CVs.





The resulting transitional surface might not fit to the scan lines. Adjust the transitional surface by modifying the shape of the blend curve.

To begin the modification of the transitional surface, note that the bottom blend curve is connected to a point inside of the curve on the side surface. For direct modeling purposes, the current blend curve arrangement is not favorable for modification. To enable alignment using the **Object Edit > Align > Align** tool, cut the reference curve at the point where the blend curve intersects the reference curve.

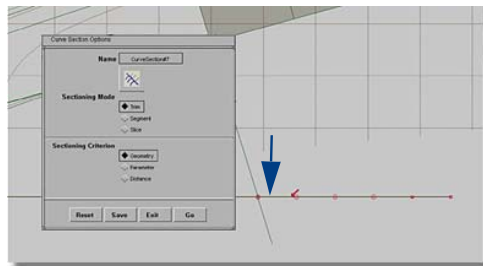


To cut the curve on the side surface and align the transitional curves to the references

- 1 Use the **Viewing Panel** to switch to the side view.
- 2 Make the newly created transition surface invisible.
- 3 Open the option box of the **Curve Edit > Curve section** tool.
- 4 Set the options as follows.



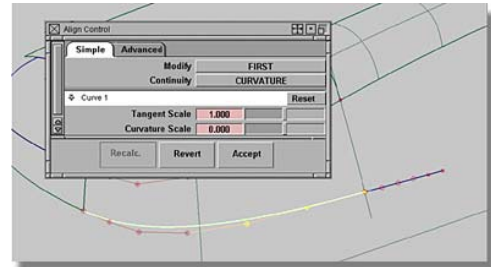
Set this parameter...	To this value
Sectioning Mode	Trim
Sectioning Criterion	Geometry



- 5 Press the **Go** button at the bottom of the option box.
- 6 Select the curve at the point highlighted in the image above.
- 7 Press the **Go** button at the bottom of the *screen*.
- 8 Select the other curve involved in the process.

The next step is to align all of the curves to their references by curvature. As a result, all of the former blend curves will gain an additional kind of history that allows CVs to be modeled directly.

- 9 Double-click the **Object Edit > Align > Align** tool to produce the option box.
- 10 Select each end of the two blend curves and align them to the reference.



- 11 After the curves are aligned, choose **ObjectDisplay > Visible** to view the transition surface.

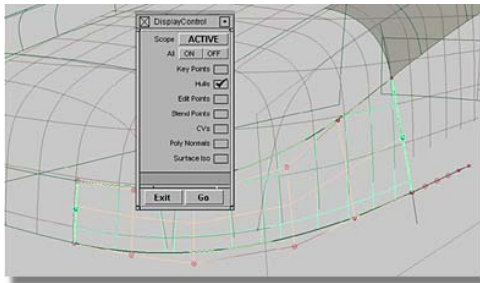
To avoid confusion when selecting curve CVs

- 1 Open the **ObjectDisplay > Control** option box.
- 2 Select the transition surface.
- 3 Set the options as follows.

Set this parameter...	To this value
Scope	ACTIVE
Key Points	off
Hulls	on
Edit Points	off
Blend Points	off
Poly Normals	off
Surface Iso	off

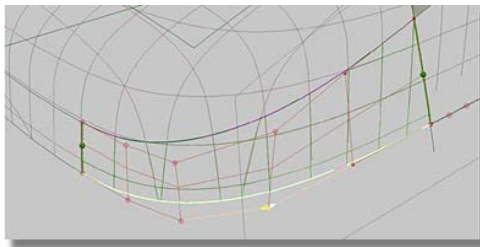
- 4 Press the **Go** button.

Although the CVs of the selected surface are hidden, the hulls that act as guides for the CV distribution are still visible. The CVs of the curves are also visible and can be selected without having to navigate a selection window.



To change the fit of the transitional surface by modifying CVs

- 1 Choose **Pick > Nothing**.
- 2 Select the transition surface.
- 3 Turn on the X, Y, and Z Cross-Sections.
- 4 Modify the CVs of the curves using the **Control Panel > Evaluate > Move CV** tool set to **SLIDE**.
- 5 Watch the sections on the surface.



The resulting surface may be flawed if a smooth fit could not be obtained between the transition surface and the scan lines. One factor that could determine the success or failure of the transition is the smoothness of the distribution of the CVs across the transition surface.

If an acceptable result cannot be achieved, increase the degree of your curves to **6**.

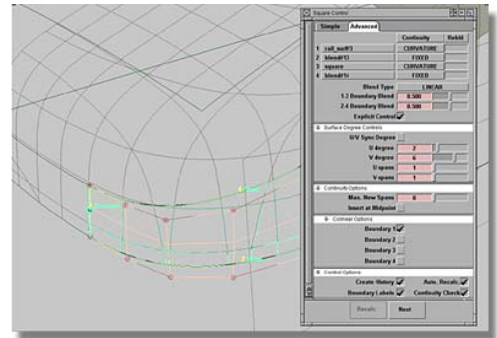
To increase the degree value

- 1 Select the first curve.
- 2 In the Control Panel, increase the degree value from **5** to **6**.
- 3 Press the **Accept** button at the bottom of the screen.
- 4 Choose **Pick > Nothing**.
- 5 Select the other curve.
- 6 Increase the Degree value to **6**.

To continue, adjust the degree of the transition surface. (Remember, by using the **Object edit > Query edit** tool, you can reproduce the option box of a surface that has a construction history).

To adjust the transition surface

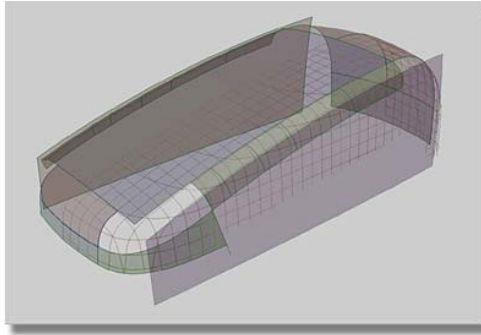
- 1 Choose the **Object edit > Query edit** tool.
- 2 Pick one edge of the transition surface. The Square Control box appears. If it does not, try repicking the edge.
- 3 Change the value of the degree from **5** to **6**.
- 4 Choose **Pick > Nothing**.



At this point, for each curve you should have one independent (free) CV that is not related to a curvature alignment. The new curves offer more freedom in fitting the transition surface to the scan lines. Within the confines of this tutorial, do not exceed a degree **6** curve. One free CV should be sufficient to maintain a good fit between the transitional surface and the scan lines.

If all CV modifications have been implemented and the results are not satisfactory, change the front surface in the same manner used to create the transitions between the front/rear surface and the top surface.

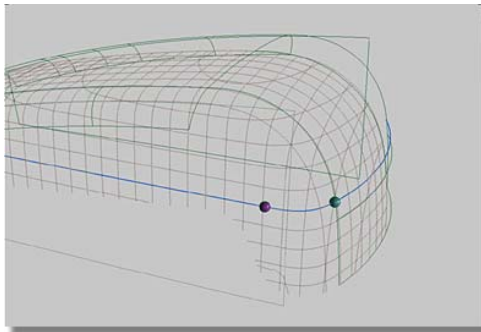
Successful modifications of the model should produce results that resemble the image below.



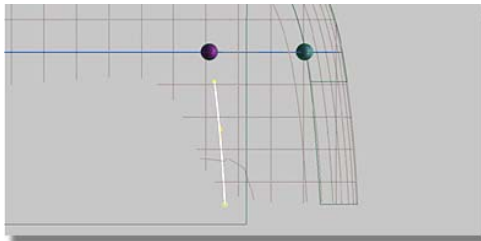
For the next step, try to construct the transition surface at the rear of the model by using the same methods already employed. Reference the images below for tips.

Constructing a Transition Surface at the Rear of the Model

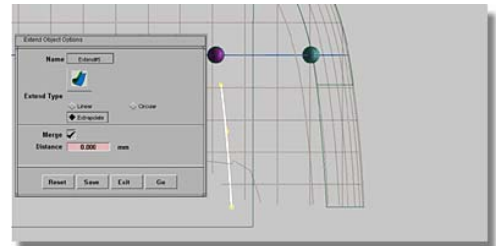
The two spheres act as markers to show the area of the transition surface.



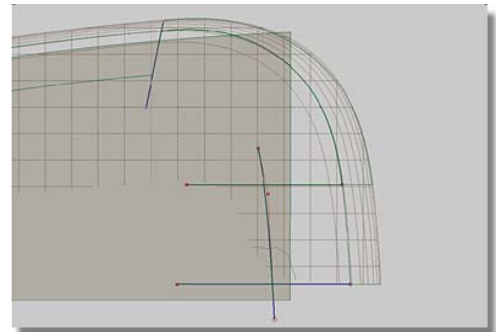
- 1 Duplicate the edge of the rear surface and move the curve in the X-direction to achieve a similar shape.



- 2 The curve has to be extended. Use the **Object edit > Extend** tool.

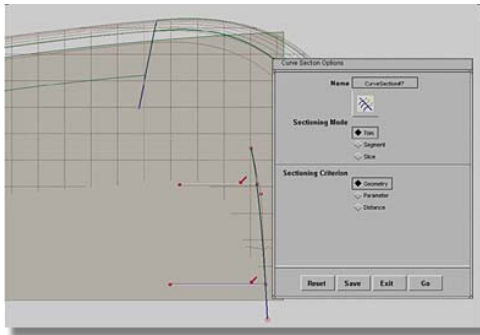


- 3 Create two additional horizontal curves to follow the edges of the rear surface.

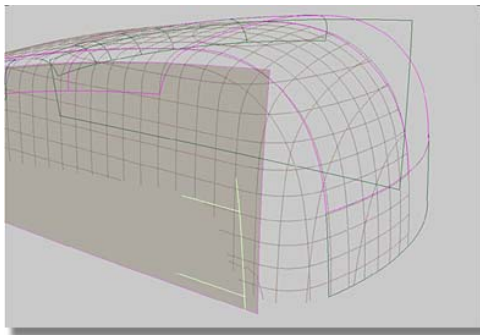
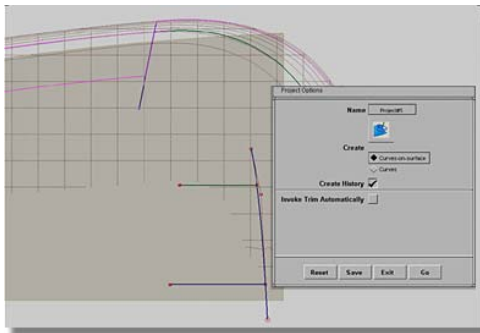


- 4 Switch to the side view and section both curves using the **Curve Edit > Curve section** tool.

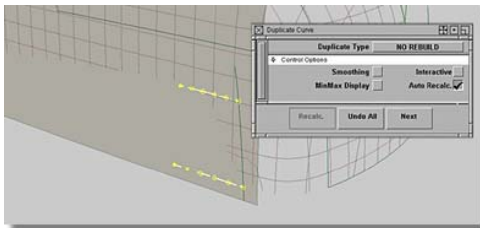




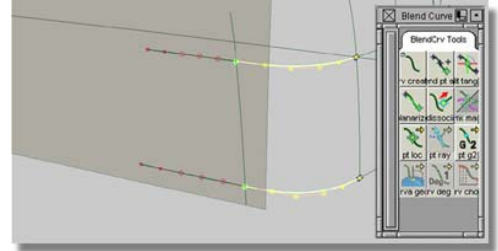
- 5 In the side view, project the three curves onto the side surface.



- 6 To create blend curves, duplicate the curve-on-surface as curves and then delete the curve-on-surface.



- 7 Having created two blend curves, select the two blend points that are connected to the curves and change their value to a **Continuity of G2**.

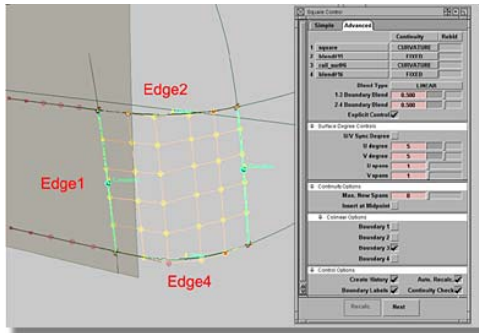


- 8 Create a square surface. Set the options as follows.

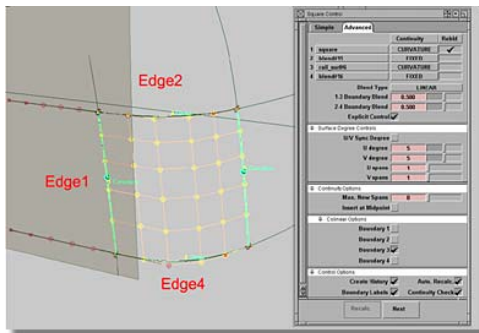
Set this parameter...	To this value
1 (square)	Set Continuity to CURVATURE, Reblid off
2 (blend #15)	Set Continuity to FIXED, Reblid off
3 (rail_surf#6)	Set Continuity to CURVATURE, Reblid off
4 (blend#16)	Set Continuity to FIXED, Reblid off
Blend Type	LINEAR
1-3 Boundary Blend	0.500
2-4 Boundary Blend	0.500
Explicit Control	on
U/V Sync Degree	off
U degree	5
V degree	5
U spans	1
V spans	1
Max. New Spans	0
Insert at Midpoint	off
Boundary 1 Colinear	off
Boundary 2 Colinear	off
Boundary 3 Colinear	on
Boundary 4 Colinear	off

Set this parameter...	To this value
Create History	on
Auto. Recalc.	on
Boundary Labels	on
Continuity Check	on

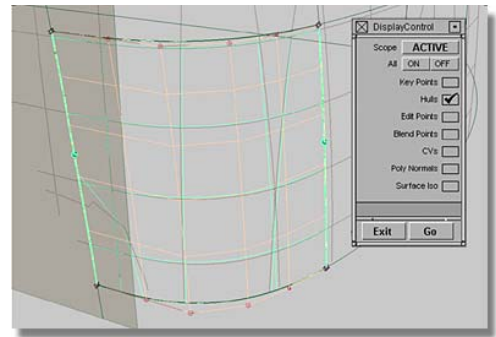
Note that edge # 1 does not utilize the **ReBld** (Rebuild) option.



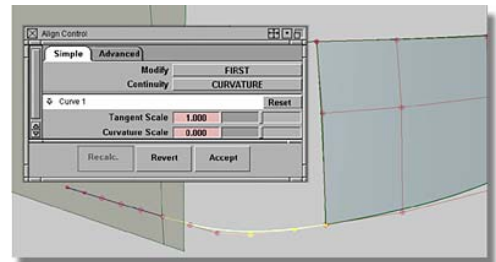
- 9 Because the resulting CV distribution of the square is not acceptable, set the **ReBld** option on edge #1 to achieve the desired results.



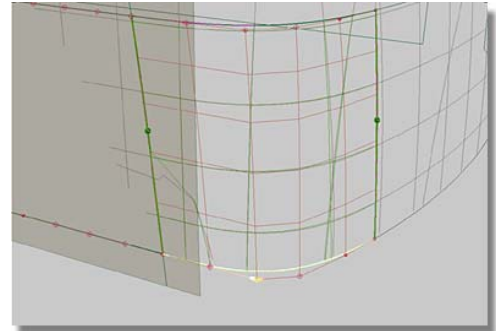
- 10 Turn on the X, Y, and Z Cross-Sections. To adjust the surface, turn off the CVs to show only the CVs required for the procedure.



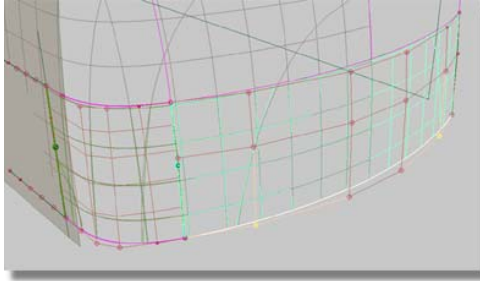
- 11 Make the surface invisible, and then use the alignment history to align the curves to their reference.



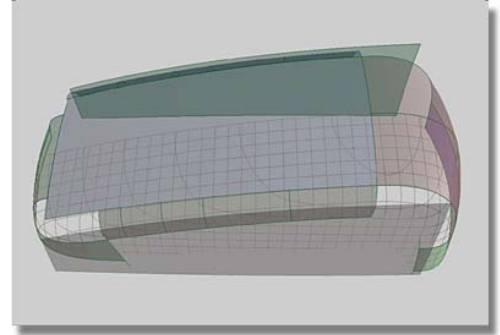
- 12 After the alignment procedure, make the surface visible again and slide the CVs to fit the transition surface to the scan lines.



- 13 If the modifications were not sufficient to fit the transition surface to the scan lines, modify the rear surface to achieve a better result.



Having completed the transition surface from the rear surface, your model should resemble the image below.



Constructing Ball Corners

The ball corner procedure is relatively straightforward but can be complicated by errors and imbalances created earlier in the model's construction.

> Rules to consider before beginning the ball corner procedure

- Ensure that the CVs are evenly distributed across the main surfaces.
- When trimming surfaces, ensure that any Curve on Surfaces are not cropped to the point where it is difficult to work with the trimmed edge.
- Because a ball corner must have a four-sided surface, the Patch Layout must be constructed in a similar fashion to avoid triangle surfaces.

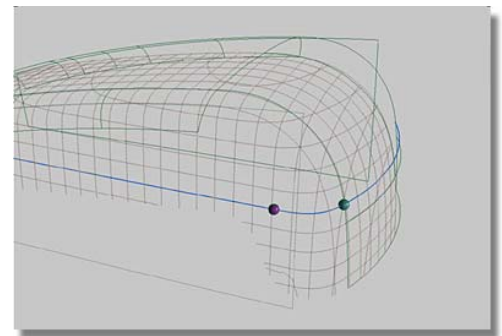
Up until this point in the tutorial, high-quality model surfaces have been produced from a mathematical point of view. Single span surfaces (except the fillets), called Bezier surfaces, were utilized to guarantee a smooth curvature comb inside of a surface.

The correct use of single span surfaces requires a high degree of experience with the **Object Edit > Align > Align** tool, direct modeling, and handling Locators. Because the experience required is outside of the scope of this tutorial, the ball corners created for this model will not use single span surfacing.



How to model a simple ball corner

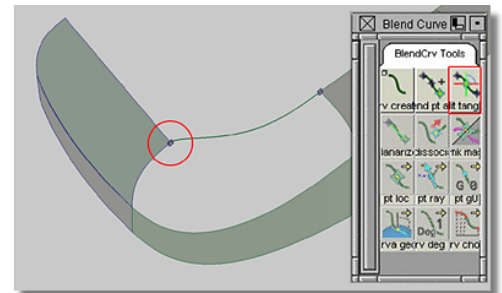
- 1 Open the wire file `Ball Corner.wire`.
- 2 Use the prepared surfaces located in the layer entitled "work".



- 3 Create a blend curve between the trimmed fillet surface and the front transition surface.



The resulting blend curve should resemble the image below. Note also that it is possible that the left blend point projects from the surface in the wrong direction. To correct this problem, consult Steps 3 – 5.



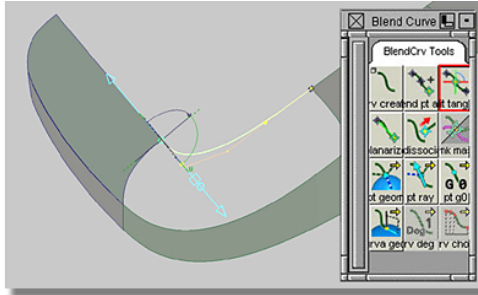
- 4 Select the blend point.



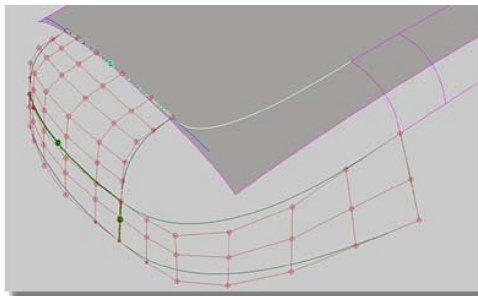
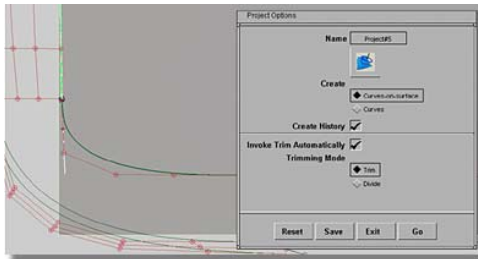
- Choose the **BlendCrv Tools > Blend curve edit** tool.
- A manipulator will appear on the selected blend curve. Click on the axis that defines the desired direction.



A green **U** or **V** should appear on the desired axis. If a black sign is produced, click on the axis again.

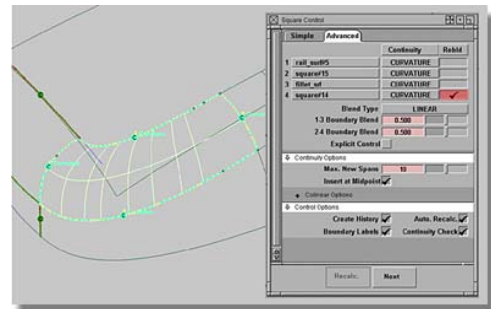


- Use the **Viewing Panel** to switch to the top view.
- To produce a curve-on-surface, project the blend curve onto the top surface.



- Set the options as follows, then, create a square surface with the projected curve set as edge # 4.

Set this parameter...	To this value
1 (rail_surf#5)	Set Continuity to CURVATURE and Reblid off
2 (square#15)	Set Continuity to CURVATURE and Reblid off
3 (fillet_srf)	Set Continuity to CURVATURE and Reblid off
4 (square#14)	Set Continuity to CURVATURE and Reblid on
Blend Type	LINEAR
1-3 Boundary Blend	0.500
2-4 Boundary Blend	0.500
Explicit Control	off
Max. New Spans	10
Insert at Midpoint	on
Create History	on
Auto. Recalc.	on
Boundary Labels	on
Continuity Check	on



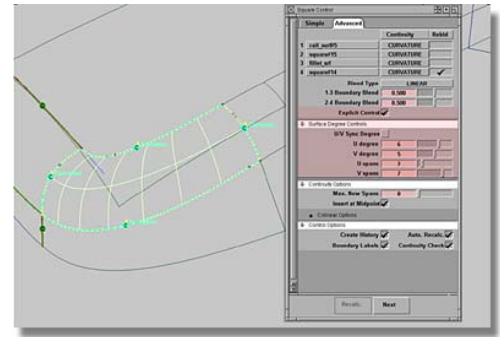
- Examine the span distribution of the square surface for irregularities.



In the above image, the span placements are irregular. Executing Step 11 will provide for a more even distribution of span lines.

- 11 In the Square Control box, use the **Explicit Control** option to change the arrangement of the square option box.
- 12 Set the Advanced options as follows.

Set this parameter...	To this value
1 (rail_surf#5)	Set Continuity to CURVATURE and Reblid off
2 (square#15)	Set Continuity to CURVATURE and Reblid off
3 (fillet_srf)	Set Continuity to CURVATURE and Reblid off
4 (square#14)	Set Continuity to CURVATURE and Reblid on
Blend Type	LINEAR
1-3 Boundary Blend	0.500
2-4 Boundary Blend	0.500
Explicit Control	on
U/V Sync Degree	off
U degree	6
V degree	5
U spans	2
V spans	7
Max. New Spans	0
Insert at Midpoint	on
Create History	on
Auto. Recalc	on
Boundary Labels	on
Continuity Check	on



There may be slight differences in the appearance of your model and the model depicted in this tutorial. For this reason, you should explore the Square Control box to find the best possible arrangement for your surface.

Judge the surface by using an evaluation tool that shows you the stripes as projected by a lamp onto selected surfaces. Try moving the lamp using the blue, green, and red manipulators to find a lighting arrangement that best accentuates your model.

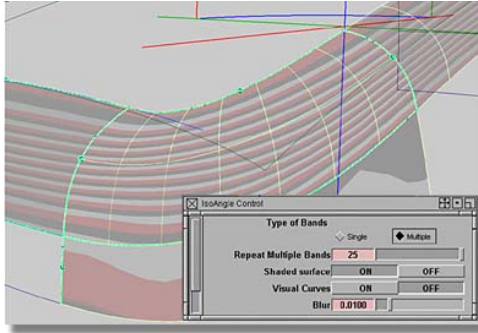
To use the IsoAngle tool

- 1 Select the surfaces to be evaluated.
- 2 Double-click the **Evaluate > IsoAngle** tool to open the option box.
- 3 Set the options as follows.

Set this parameter...	To this value
Type of Bands	Multiple
Repeat Multiple Bands	25
Shaded surface	on
Visual Curves	off
Blur	0.0100

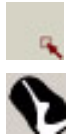
- 4 Zoom out of the view to show the lamp.
- 5 Click on the colorized circle to move the lamp. Examine the highlights of the model surface.



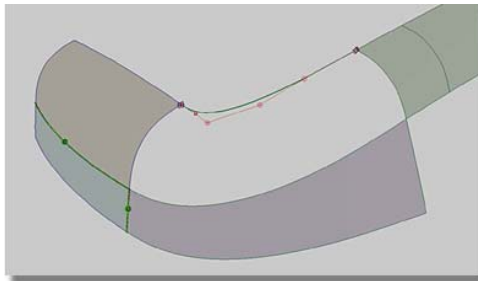


At this point in the modeling process, the front-end of the model is complete. However, if you are not satisfied with the results presented by the **Evaluate > IsoAngle** tool, modify the ball corners using the direct modeling method. When direct modeling the ball curve, the number of CVs will have to be reduced, which in turn, will reduce the number of spans.

To reduce the number of spans



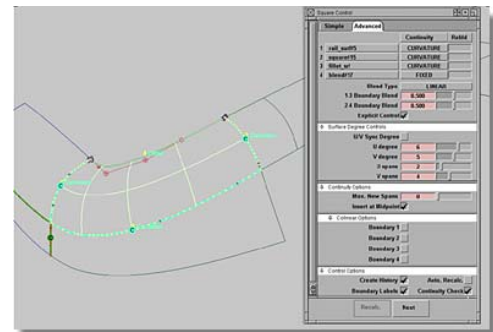
- 1 Choose **Pick > Nothing**.
- 2 Tumble the scene as shown in the image below.
- 3 Turn off the **Evaluate > IsoAngle** tool.
- 4 Make the top surface invisible.



For this exercise, a curve-on-surface will not be used to create the ball corner because the result will involve a mathematical evaluation that could produce a high number of spans. Instead, this exercise will produce a ball corner using a blend curve that should produce fewer spans.

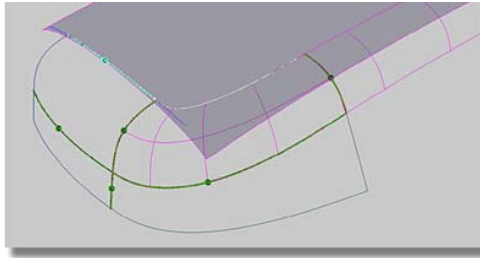
- 5 Create a square surface with the options set as follows..

Set this parameter...	To this value
1 (rail_surf#5)	Set Continuity to CURVATURE and Reblid off
2 (square#15)	Set Continuity to CURVATURE and Reblid off
3 (fillet_srf)	Set Continuity to CURVATURE and Reblid off
4 (blend#17)	Set Continuity to FIXED and Reblid off
Blend Type	LINEAR
1-3 Boundary Blend	0.500
2-4 Boundary Blend	0.500
Explicit Control	on
U/V Sync Degree	off
U degree	6
V degree	5
U spans	2
V spans	4
Max. New Spans	0
Insert at Midpoint	on
Create History	on
Auto. Recalc	off
Boundary Labels	on
Continuity Check	on



The newly created square surface has no connection to the top surface.

- To project the edge of the new square onto the top surface, switch to the top view.
- Project the edge of the ball corner onto the top surface.

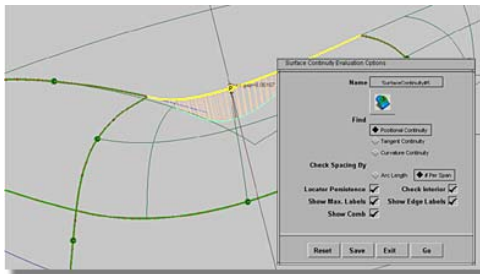


- To measure the **POSITION Continuity (G0)** between the projected curve-on-surface and the surface edge of the ball corner, double-click the **Evaluate > Continuity > Surface continuity** tool to produce the options box.
- Set the options as follows..



Set this parameter...	To this value
Find	Positional Continuity
Check Spacing by	# Per Span
Locator Persistence	on
Check Interior	on
Show Max. Labels	on
Show Edge Labels	on
Show Comb	on

- Press the **Go** button.
- Pick the projected curve-on-surface.

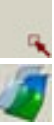


The results from the **Evaluate > Continuity > Surface continuity** tool show a small gap between

the surface edge and the curve-on-surface. The surface will need to be aligned to the curve-on-surface.

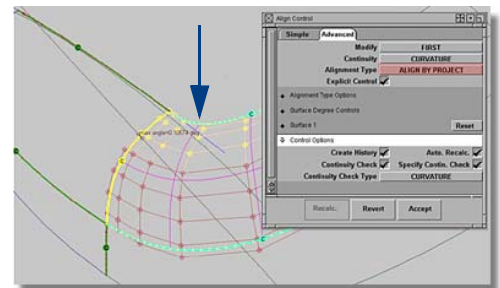
To align the surface with the curve-on-surface

- Choose **Pick > Nothing**.
- Double-click the **Object Edit > Align > Align** tool to produce the options box.
- Set the Advanced options as follows..



Set this parameter...	To this value
Modify	FIRST
Continuity	CURVATURE
Alignment Type	ALIGN BY PROJECT
Explicit Control	on
Create History	on
Auto. Recalc.	on
Continuity Check	on
Specify Contin. Check	on
Continuity Check Type	CURVATURE

- Select the edge of the ball corner surface close to the curve-on-surface.
- Select the curve-on-surface.
- Choose the **Accept** button.



It is possible that the alignment procedure will destroy the curvature continuity between the ball corner surface and the front-end transitional surface. To correct this problem, use the **Object Edit > Align > Align** tool again to restore the broken curvature connection. Before attempting another alignment, delete the construction history of

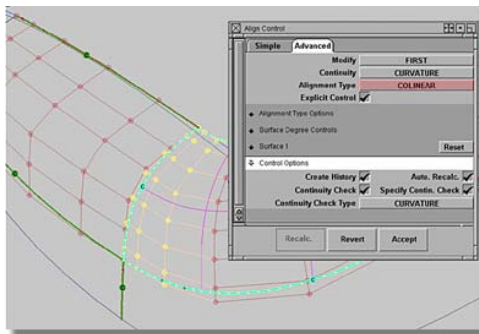
the first alignment. The second alignment process could damage the results of the first alignment process; in this case, set the **Continuity** option to **TANGENT** instead of **CURVATURE**. If the alignment remains damaged after restoration attempts, a work-around can be executed.

A work-around for restoring a broken curvature connection

The mathematical behavior of a curve-on-surface derived from the **Surface Edit > Create CurvesOnSurface > Project** tool differs from a curve-on-surface derived from the **Surface Edit > Create CurvesOnSurface > Project normal** tool.



- 1 Delete the curve-on-surface of the top surface that was used to create the ball corner.
- 2 Choose the **Surface Edit > Create CurvesOnSurface > Project normal** tool. Project the ball corner edge onto the top surface to produce a new curve-on-surface, complete with a new mathematical behavior.
- 3 Repeat both alignment processes.



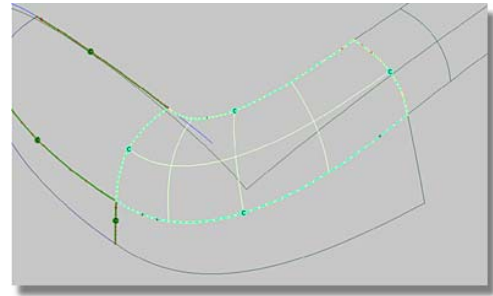
The last possibility to adjust the alignment of the ball corner is to directly manipulate CVs.

Begin by aligning the ball corner to the top surface.

Then, generate a **TANGENT Continuity** between the ball corner and the front-end transitional surface by using the **PROJ** (project) option in the **Control Panel > Evaluate > Move CV** tool.

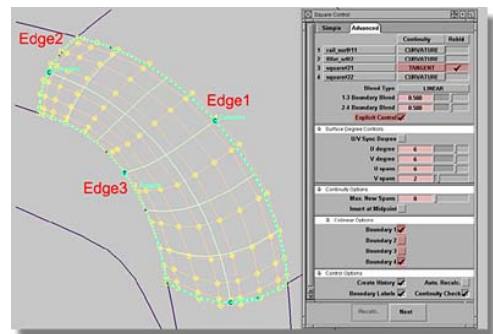
Before you modify the CVs by hand, you must delete the construction history.

The end result of this exercise should be a balled corner with less spans than those created by the curve-on-surface used in the construction of the initial square.



To finish the rear ball corner

To create a square surface, use the edges of the transition surfaces, the fillet surface, and a curve-on-surface. Once you have a new square surface, experiment with the various options of the **Surfaces > Boundary Surfaces > Square** tool to find the best possible CV distribution.

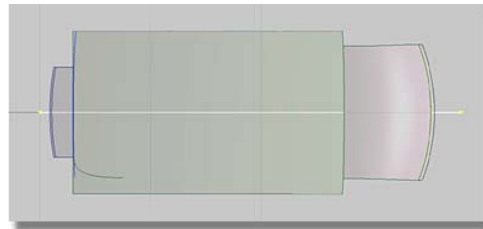


FINISHING THE MODEL

The finishing work mainly involves trimming the entire curve-on-surface. All of the surfaces that cross the Y0 plane need to be trimmed. The fillet surfaces and ball corners only exist on one half of the model, and as such, will not require any additional modifications. After the completion of the trim work, the half-model can be mirrored.

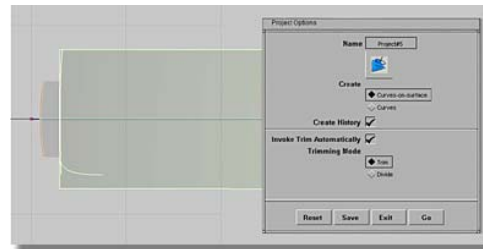
To trim the surfaces that cross the Y0 position

- 1 Choose the **WindowDisplay > Toggles > Grid** menu item.
- 2 Create a degree 1 edit point curve using the Snap to Grid function (press the **Alt** button). The curve must divide the model into halves.



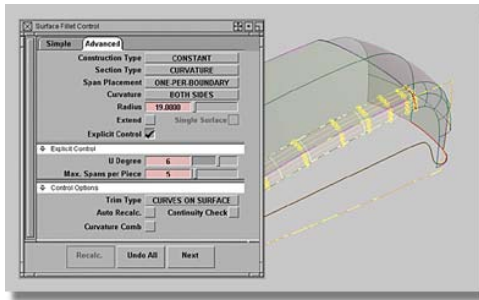
Trim the curve-on-surface to prepare the half-model for mirroring.

- 3 Select all surfaces that cross the Y0 plane.
- 4 Switch to the top view using the **Viewing Panel**.
- 5 Project the curve onto the surfaces.



- 6 Choose the **Object edit > Query edit** tool.
- 7 Select the fillet surface. The **Object edit > Query edit** tool will produce the fillet surface option box.
- 8 In the Surface Fillet Control box, change the **Trim Type** to **CURVES ON SURFACE** in order to create a curve-on-surface on the side surface and the top surface.

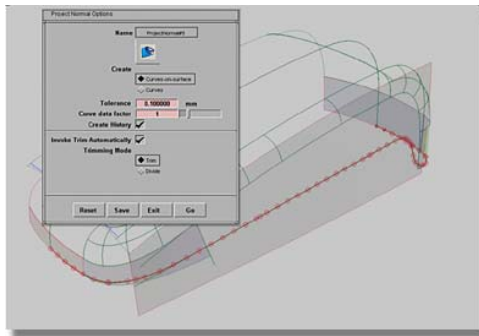




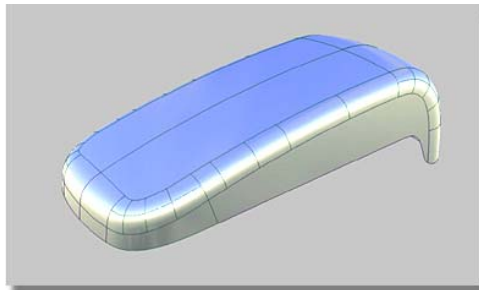
To build your knowledge, you can delve deeper into SurfaceStudio to learn advanced techniques and tools such as Bezier surfaces, the full breadth of evaluation tools, and how to construct your own Patch Layouts.

And remember, practice makes perfect ... enjoy!

- 9 Make the layer "aw edge" visible.
- 10 Using the **Surface Edit > Create CurvesOnSurface > Project normal** tool, project the edge curve onto the front/rear surface, both transition surfaces, and the side surface.



- 11 Trim the surfaces.
- 12 Assign all the surfaces to one layer.
- 13 Turn on the symmetry of that layer.



If your model resembles the above image, you have successfully completed the tutorial. Congratulations!

In this tutorial you have been introduced to the fundamental tools and methods that should provide you with a solid foundation for your surface modeling endeavors.

ADVANCED SURFACE MODELING

An overview of the core competencies required for advanced surface modeling.

In the **Foundations of Surface Modeling** tutorial you were exposed to the degree of craftsmanship required of a surface modeler. And you were introduced to SurfaceStudio, your new tool that allows you to perform surface modeling in the same manner as traditional methods. You may have traded in the workshop for a virtual space, but the core competencies of surface modeling are still the same.

Required competencies for mastering the craft of surface modeling

- the core tools
- the character of the material to be worked (wood, leather, steel)
- the critical evaluation of the finished work

To provide you with the tools and knowledge necessary to become a master craftsman in the arena of surface modeling, the following topics will be addressed in this tutorial:

Master the Critical Tools

- Blend curves
- Align Tool
- Surface Fillets

Master the Geometry Elements

- NURBS vs. Bezier surfaces

Master Surface Evaluation

- Global Evaluation
- CV Distribution
- Span Distribution
- Diagnostic Shading

Learning objectives

In this overview, you will gain an understanding of the critical tools required for class A surfacing, and will gain control over the quality of surfaces built by using the surface evaluation tools.

Handling Blend Curves

Blend curves are special free curves whose characteristics are constrained by the placement of blend points upon their shape.

Available placement types for blend points

- free placement in the scene
- snap to geometry
- snap to grid

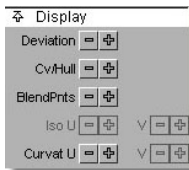


Blend points are the sole avenue for modifying blend curves. Before a blend curve can be modified, the blend points must first be selected. To select blend points, a new tool has been added to the Pick tab in SurfaceStudio 10.0 - the **Pick > Point Types > Blend point** tool.



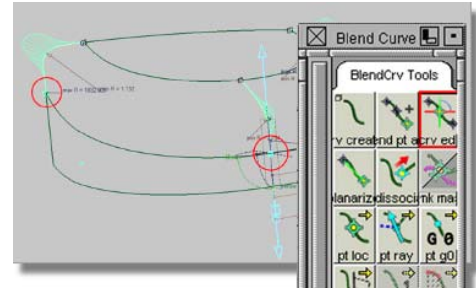
Selected blend points can be modified or deleted in the same manner as other geometry items.

As well, in the same fashion that the visibility of CVs can be manipulated via the Control Panel, the visibility characteristics of blend points are also available for manipulation.



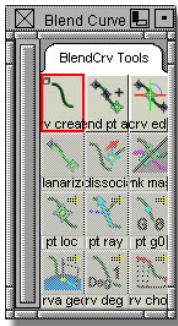
SurfaceStudio allows for the simultaneous selection of multiple blend points. In the image below, three

blend points have been selected for modification with the **BlendCrv Tools > Blend curve create** tool.

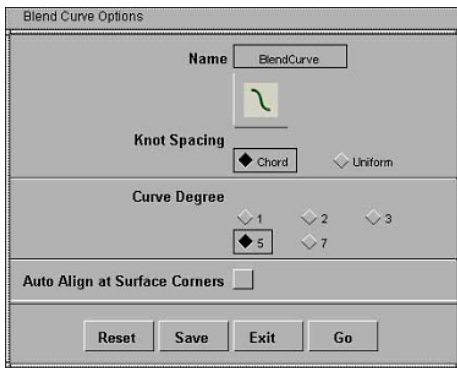


Crucial Blend Curve Tools

Blend curve create



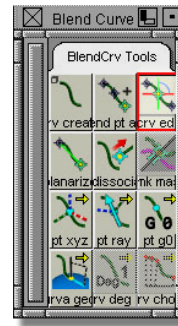
To create a blend curve, use the **BlendCrv Tools > Blend curve create** tool. Double-clicking the icon in the blend curve toolbox will produce an option box associated with the tool.



The **Knot Spacing** option is set to Chord by default and should not be changed unless warranted by extraordinary circumstances.

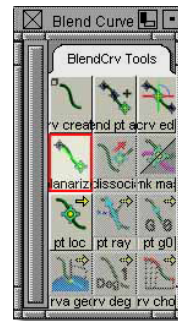
Enabling the **Auto Align at Surface Corners** button creates a **PARAMETRIC Curvature type** when a blend point is attached to a surface corner. The resulting curvature will align the blend curve along the edge at the corner. If the **Auto Align at Surface Corners** button is not enabled, a **GEOMETRIC** curvature type will be employed. The resulting blend curve will not be specifically aligned to an edge.

Blend curve edit tangent



By clicking the **BlendCrv Tools > Blend curve create** tool, a manipulator is generated from the selected blend point. This tool does not change the type of curvature.

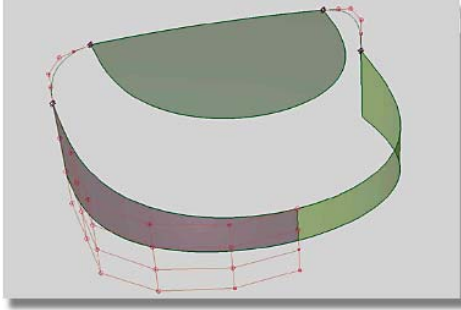
Blend curve planarize



The **BlendCrv Tools > Blend curve planarize** tool is useful for pressuring blend curves into a plane. Although employing a **GEOMETRIC Curvature type** will result in a blend curve constrained to a plane, there are situations that require a construction plane. And, there are situations that require blend curves of a **PARAMETRIC Curvature type** associated with one blend point while the other blend point(s) remain free.

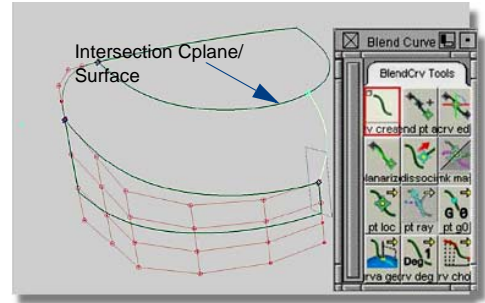
The image below depicts a surfacing example in which the transition curves between the base surface and the top surface are to be modeled. The primary restriction of the situation is that the curves must be oriented at the U/V parameter (isoperimetric lines) of the base surface. In addition, one curve is absent, and given the example, it is unclear as to where the missing curve will attach to

the top surface. This example is tailor-made for the **Planarize** tool.

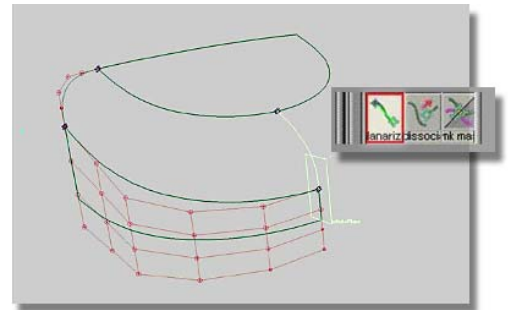


The **Planarize** tool works best when using a pre-defined construction plane. In this arrangement, the blend curve is pressed into the construction plane while maintaining the continuity of the reference geometry.

To execute this procedure, begin by creating the construction plane, then create a blend curve between the base surface and the top surface.

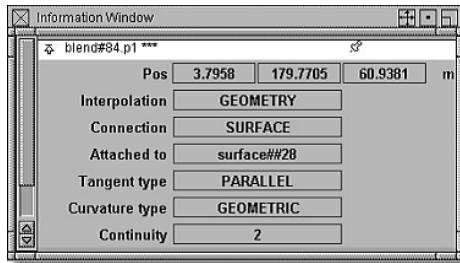


Make sure that the blend point(s) and the construction plane are both selected, then choose the **Planarize** tool. The result is that the blend point associated with the top surface moves to a position where the construction plane intersects with the top surface. The blend curve will then connect both surfaces by curvature and while maintaining a smooth planar character.



Information Provided by Blend Curves

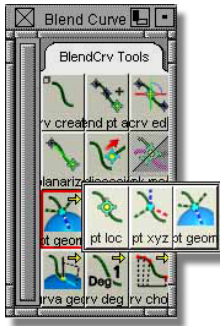
To gain access to the information contained within a blend curve, use the **Windows > Information > Information window** menu item after selecting an associated blend point.



Primary options presented in the Information Window

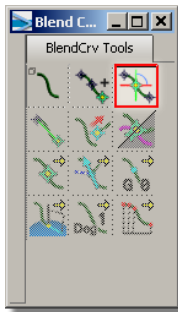
- Interpolation
- Connection
- Tangent type
- Curvature type
- Continuity

Interpolation



This tool set allows the user to specify a direction type that determines how a blend curve passes through a blend point. For surface modelers, the **BlendCrv Tools > Constraint Interpolation Direction > Blend constraint interp geometry** tool is of particular interest. This tool aligns the blend curve to the reference geometry using a **PARAMETRIC Curvature type** that results in a similar curvature alignment to that achieved with the **Object Edit > Align > Align** tool.

The **LOCATION** setting is the **Interpolation** default for each new blend curve. The other **Interpolation** settings, **DIRECTION** and **GEOMETRY**, each offer a manipulator that can be accessed via the **BlendCrv Tools > Blend curve edit** tool.

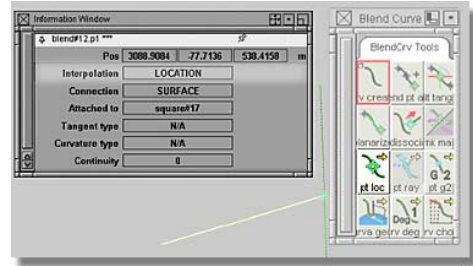


The **Interpolation** type can be changed by using the highlighted buttons in the images below.

Three types of Interpolation

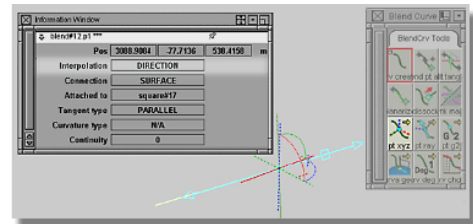
1 LOCATION

This setting forces the blend curve to pass through the blend point's location in space.



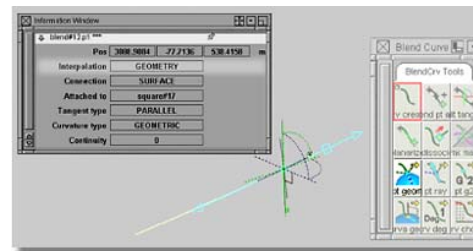
2 DIRECTION

This setting forces the blend curve to pass through the blend point's location in space while travelling in a dictated world space direction.



3 GEOMETRY

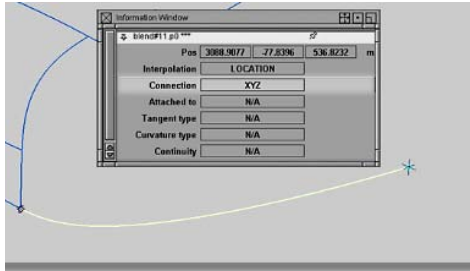
This setting forces the blend curve to pass through a point on a curve or surface and travel in a direction relative to a curve or surface.



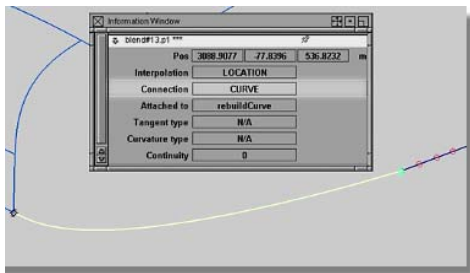
Connection

Blend curves attach to four geometry objects

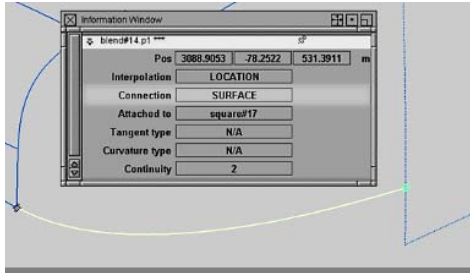
1 Construction Points



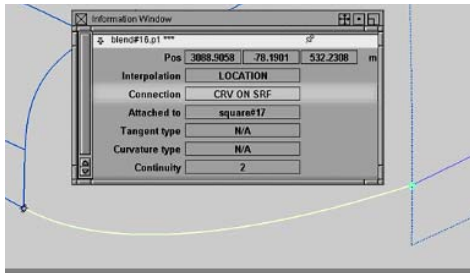
2 Curves



3 Surfaces / Isoparametric Lines



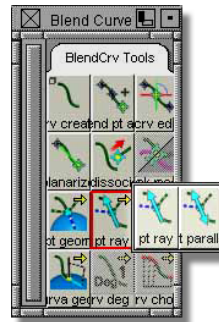
4 Curves-on-Surface



Tangent type

The **Tangent type** option specifies a direction that dictates how a blend curve relates to blend point(s).

There are two **Tangent types** that are defined using the **Constraint Interpolation Direction** tool found in the blend curve toolbox.



Blend constraint directed (pt ray): sets an actual direction for the curve tangent. Use this **Tangent type** when the specific tangent direction at the location of the blend point is important.

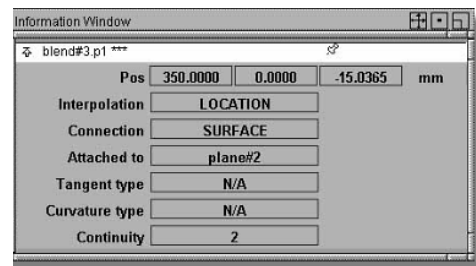
Blend constraint parallel: sets a line along the curve that passes (in either direction) through the blend point. This option is easier to enforce and results in a better curve continuity.

Curvature type

This option is an important component of blend points when blend curves are attached to a surface.



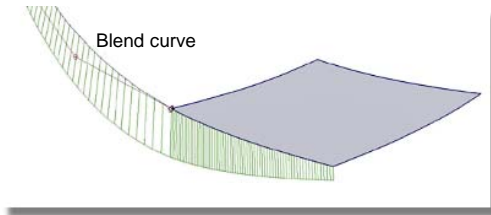
To see the **Curvature type** in the Information Window, the blend point must be selected. If the Information Window returns a **N/A** value, select the **Edit Tangent** tool. The **Curvature type** will then be properly populated.



There are two curvature types available, **PARAMETRIC** and **GEOMETRIC**.

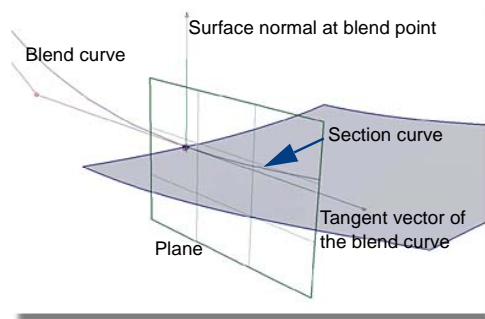
> PARAMETRIC

This type of curvature is similar in behavior to the **Object Edit > Align > Align** tool. In general, when attaching a blend curve with **PARAMETRIC** curvature to a surface, the result will appear similar to that achieved by aligning a blend curve to the isoparametric direction of a surface.



> GEOMETRIC

This type of curvature draws upon a plane constructed from the surface normal at the blend point and the tangent vector of the blend curve. By intersecting the plane with the surface, a section curve can be created that will allow for the alignment of the blend curve.



Continuity

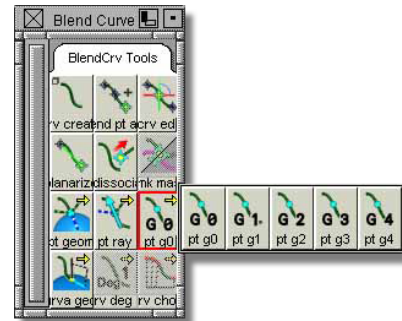
This option defines the quality of the blend curve as it passes through the point in space associated with the blend point.

Three types of Continuity

- **G0 - POSITION** continuity, affects the first CV of the blend curve
- **G1 - TANGENT** continuity, affects the first two CVs of the blend curve
- **G2 - CURVATURE** continuity, affects the first three CVs of the blend curve

Continuity types, **G3** and **G4**, require the automatic insertion of additional spans to the blend curve. Usually, **G2 Continuity** is sufficient for meeting the requirements of a surface modeling project.

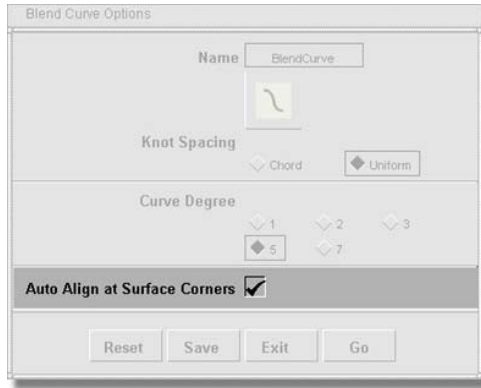
To set the **Continuity** type, the blend point must be selected. As detailed in the image below, use the highlighted tool found in the blend curve toolbox to change the **Continuity** type.



Blend Curves as Transition Curves

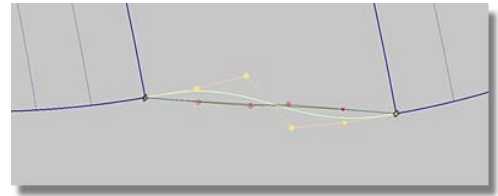
Auto Align at Surface Corners

When constraining a blend curve to surface corners it is expected that the blend curve will be aligned to the surface edges. To automatically constrain the blend curve, the option **Auto Align at Surface Corners** must be enabled in the option box for the **BlendCrv Tools > Blend curve create** tool. The blend points of the blend curve will automatically receive a **PARAMETRIC** constraint.



Without the automatic alignment of the blend points, the blend curve will be generated with a

GEOMETRIC constraint approach at the blend points. The geometric alignment will differ from the shape of a curve that is simply aligned to the surface edges.

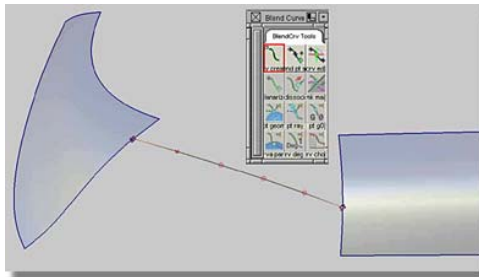


The image above shows two blend curves. The highlighted curve was created using the activated **Auto Align at Surface Corners** option while the other blend curve was created without the option.

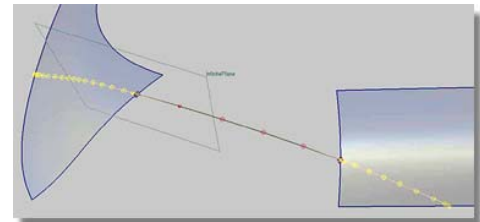
Blend Curve Constraint to a Surface Edge

The Geometric Approach

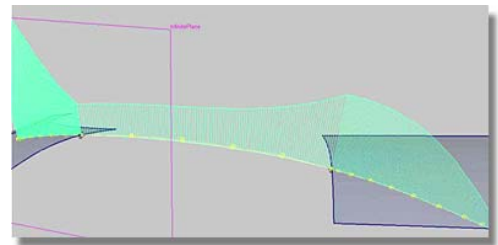
To create a blend curve between the edges of two surfaces, but not at the corners, snap the blend points to the surface. The resulting planar blend curve will always contain geometry constrained blend points and will have the curvature continuity of the reference surface.



For a better understanding of the geometric curvature type, create a construction plane using three points snapped to the blend curve. Then, in the Control Panel, specify and calculate the sections in such a manner that the intersections between the surfaces and the construction plane appear as curves.



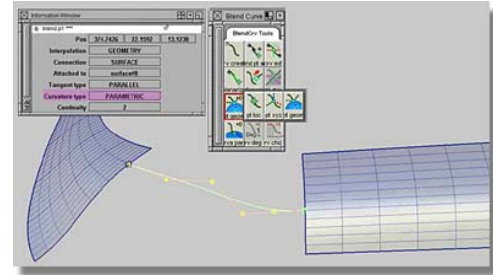
Both the intersection curves and the blend curve can be analyzed with the curve curvature tool. The curvature comb, as seen in the image below, details that the blend curve is planar and is curvature aligned to the two curves created by the intersection between the construction plane and both surfaces.



The Parametric Approach

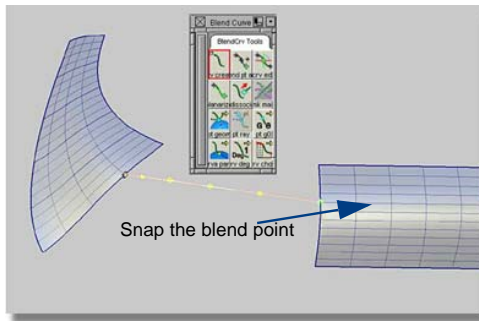
Another option for aligning a blend curve to more than one surface is to use the parametric constraint that employs the U/V directions of the surfaces. The parametric method is very useful when creating transition surfaces that must follow the parameter

flow of both surfaces. To achieve this behavior, select the blend points first, then choose the Geometry type by clicking the **BlendCrv Tools > Constraint Interpolation Direction > Blend constraint interp geometry** tool. Using the parametric method, a blend curve aligns to the appropriate isoperimetric line that represents the current U/V direction. In the Information Window, the **Curvature type** changes to **PARAMETRIC**.

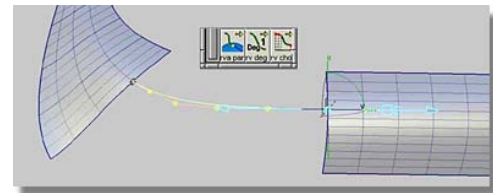


Blend Curve Constraint to an ISO parameter

To create a blend curve constraint to an isoperimetric line, snap the blend points onto the isoperimetric lines. The resulting blend curve has a **GEOMETRIC Curvature type**. Because of this calculation method, the blend curve is not following the isoperimetric line.

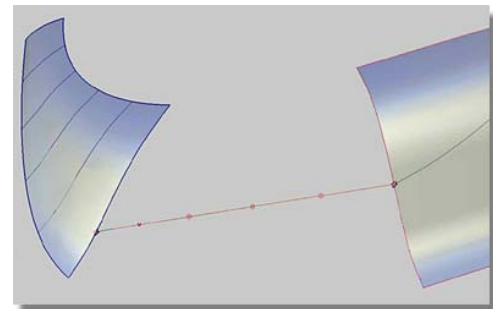


To follow the isoperimetric line, select the blend points first then change the **Curvature type** to **PARAMETRIC**. The shape of the curve changes so that the blend curve properly aligns to the isoperimetric line.



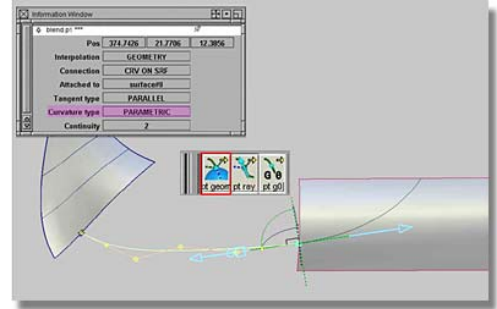
Blend Curve Constraint to a Curve-On-Surface

To constrain a blend curve to a curve-on-surface, snap the blend points to the curve-on-surface. The blend point connected to the curve-on-surface has a **GEOMETRY** constraint.



When aligning a blend curve to a curve-on-surface, select the blend point that is constrained to the curve-on-surface, then click the **GEOMETRY** button.

The **Curvature type** changes to **PARAMETRIC** and the blend curve aligns to the curve-on-surface.

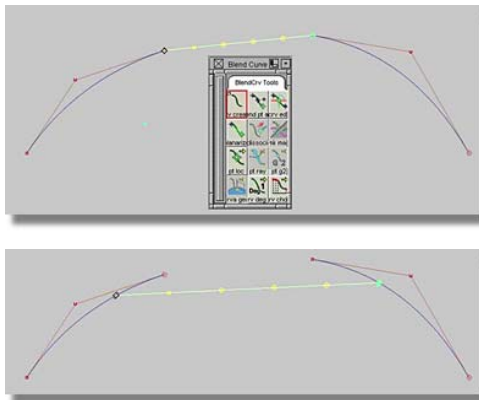


Blend Curve Constraint to a Curve

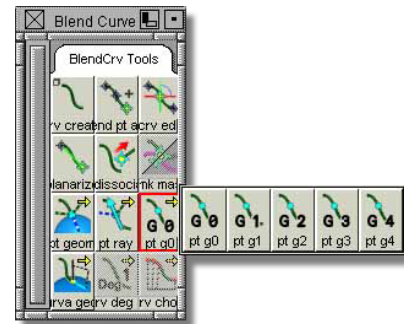
When a blend point's lone attachment is to a curve, the **Continuity** type is always **G0**. This arrangement occurs when a blend curve is attached to an endpoint of a curve, or to an inner part of a curve.



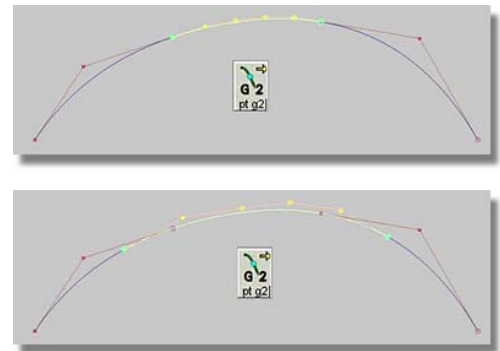
Make sure to use the "Snap to Curve" mode (**Ctrl + Alt**) when attaching a blend point to a curve.



To align a blend curve to a curve, begin by selecting the blend point(s). As detailed in the image below, to change the **Continuity** setting, use the expanded tool set found in the blend curve toolbox.



By choosing the **BlendCrv Tools > Constraint Continuity > Blend constraint G2** icon, the blend curve aligns to the curve.



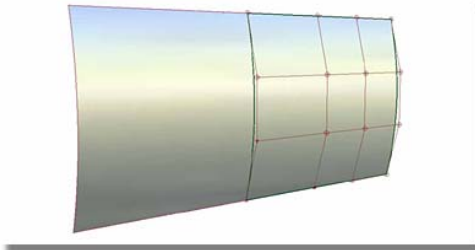
The Align Tool

Understanding the Align Tool

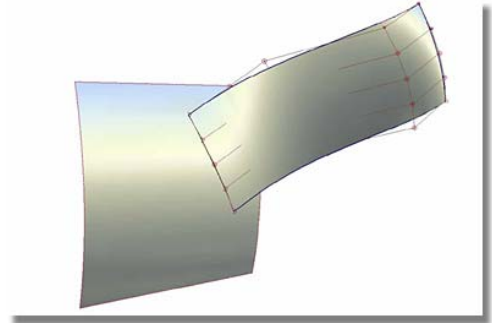
Mastering the **Object Edit > Align > Align** tool is integral to the art of constructing quality surfaces. Typically, the **Align** tool is used in direct modeling methods.

The Align tool connection types

- connect two curves
- connect two surfaces aligned at the edges



- connect two surfaces aligned at the inner part of the reference surface



- connect a curve to a surface edge
- connect a curve to the inner part of a surface (helping geometry such as an isoperimetric line or curve-on-surface)

The rules are the same when aligning either surfaces or curves. But, the alignment of surfaces is more complex in detail and variations. For this reason, the following examination of the **Align** tool will deal specifically with the alignment of surfaces. The information gained from this tutorial can easily be adapted for aligning curves.

Handling the Align Tool

Basics - Simple and Advanced Mode

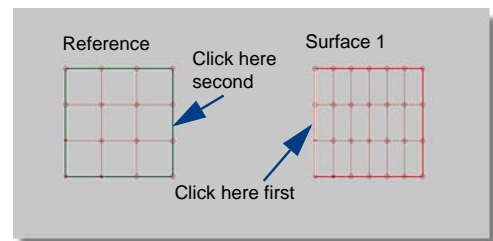
The **Align** tool's option box features a simple and an advanced mode. To master the **Align** tool, it is necessary to work with the advanced mode but to reduce visual clutter, some of the images in this tutorial use the simple mode.

Basics - Selection Algorithm

An alignment situation usually features a reference geometry (a curve or surface) and a geometry that is to be aligned. Within the confines of this tutorial, the reference geometry will be referred to as "the Reference" and the surface to be aligned will be referred to as "Surface 1".

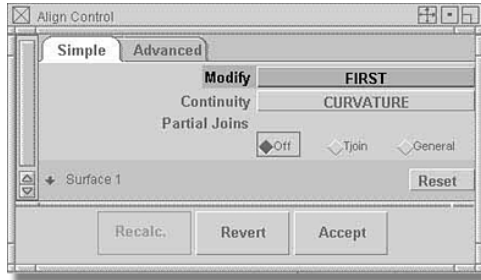
The selection algorithm requires that Surface 1 should always be selected first. It is important to note that when selecting Surface 1, the end of the

geometry closest to the point of intended alignment should be selected. In situations where the Reference is a surface, the Reference edge must be clicked explicitly.



In most cases, the Reference remains at a fixed location, leaving all modifications to be enacted on Surface 1. To restrict the modification of the

Reference, set the **Modify** option to **FIRST** as shown in the image below.



Basics - Undo

When using the **Align** tool, it is impossible to use the **Edit > Undo** command found in the SurfaceStudio main menu. The **Align** tool does, however, offer its own undo functionality that is executed via the **Revert** button found in the tool's option box.

As long as Surface 1 has an associated history, the **Revert** button steps the alignment procedure back to the last freeze point, or to the beginning of the procedure.

Clicking the **Accept** button freezes the alignment procedure.

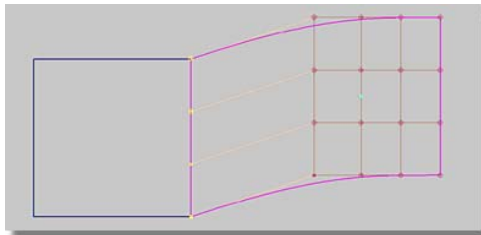
Continuity

The **Continuity** option dictates the quality of the alignment.

The execution of the alignment procedure changes the CV distribution of Surface 1. The number of influenced CVs depends on the quality set in the **Continuity** option.

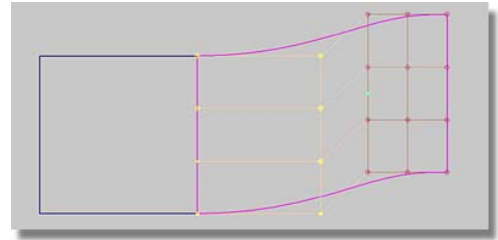
> POSITION

The first CV row will be moved to fit the edge of the Reference.



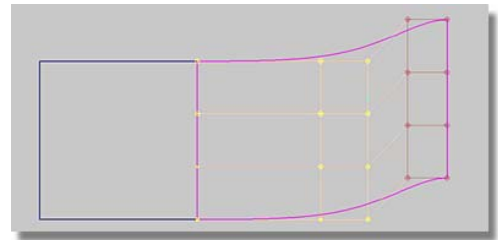
> TANGENT

The first and the second CV rows will be adjusted. The second row is responsible for achieving **TANGENT** continuity.



> CURVATURE

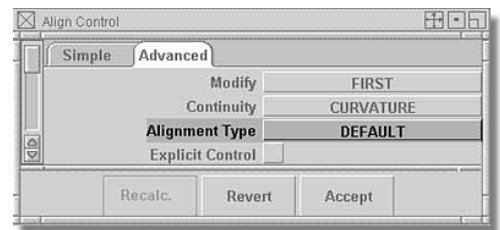
In addition to the first and the second rows, the third CV row will be moved.



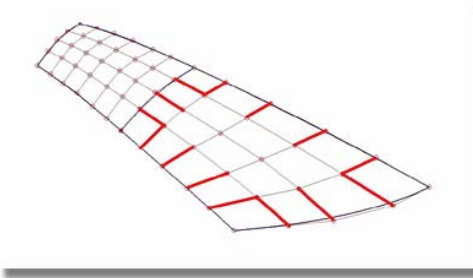
Depending on the quality of the selected continuity, the influenced rows are always highlighted in yellow.

Alignment Type

Within the **Alignment Type** option, there are a number of settings that dictate the specific CV distribution on Surface 1.



An examination of tangents will help to foster a better understanding of CV distribution.



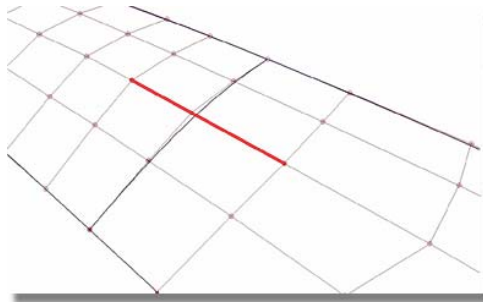
In the above image, the red (bolded) lines are tangents. In basic terms, a tangent is the line that connects the first CV of an edge (the endpoint of a curve) and the second CV.

Tangent Criteria

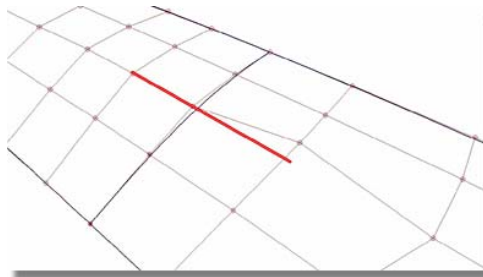
When aligning surfaces by their edges, there are two criteria that must be considered.

1 Colinearity

In this method, the tangents of each surface are in line.



The above image shows two surfaces with colinear tangents.



The above image shows two surfaces with broken colinearity.

2 Tangent Length Ratio

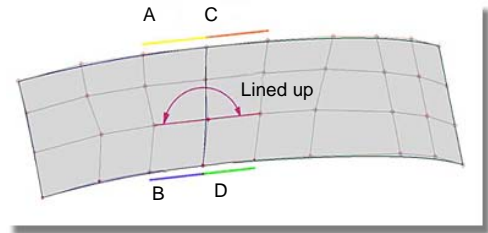
The Reference has a specific CV distribution that is determined by the lengths of the tangents. Similar tangent length ratios must be considered for Surface 1 when executing the alignment procedure. The tangent length ratios of Surface 1 must be fixed to those of the Reference.

To manage the alignment methods, SurfaceStudio offers an **Alignment Type** option that contains the following settings.

> DEFAULT

The **DEFAULT** setting is typically used when aligning the edges of two surfaces. In general, the **DEFAULT** setting produces an ideal alignment in terms of a well-balanced geometry (the CVs are lined up in a colinear fashion). As well, Surface 1 tangents will have the same length ratio as found in the Reference.

Length of A / Length of B = Length of C / Length of D



The **DEFAULT** setting often executes dramatic changes to the CV distribution of Surface 1. As a result, discontinuity in terms of equal length ratio of tangents at the Reference will be visible on Surface 1.



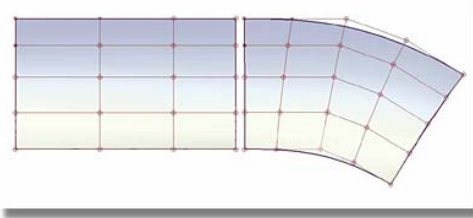
The **DEFAULT** setting can be used as a tool for evaluating the equal length ratio of tangents of surfaces.

> COLINEAR

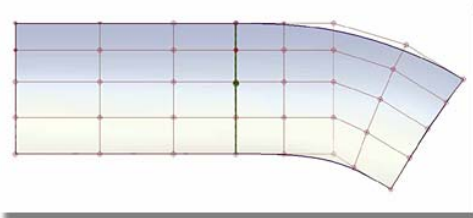
Similar to the **DEFAULT** setting, the **COLINEAR** setting is typically used when aligning the edges of two surfaces. But while the tangents are fixed colinear, the tangent length ratios are not fixed, allowing the tangents to remain independent.

The colinear setting is used primarily to align a surface with the Reference when the two surfaces have widely different CV distributions.

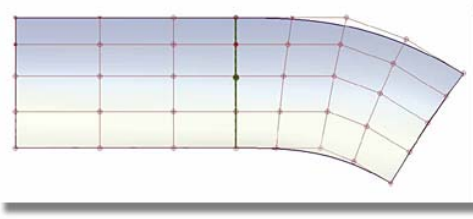
In the following three images, the Reference is left-justified while the Surface 1 is right-justified. The three References have a rectangular CV distribution while the three Surfaces 1s have a radial CV distribution.



Using the **DEFAULT** setting, both alignment criteria will be fixed. Colinearity is maintained, and Surface 1 and the Reference have the same tangent length ratio. However, the radial criteria of Surface 1 will be destroyed.



Using the **COLINEAR** setting, the tangent length ratios will not be fixed, but colinearity will be maintained.



> ALIGN BY PROJECT

In situations where the **DEFAULT** and **COLINEAR** settings are employed, the impact on Surface 1 is often significant. As a result, in order to use these two options, the Reference must have an immaculately clean CV distribution.

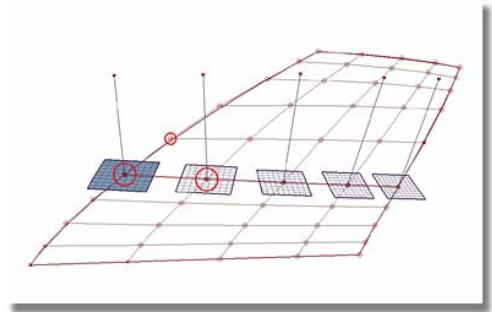
To provide for a measure of flexibility, **Project** alignment offers a lesser degree of impact on the CV distribution of Surface 1 when creating the required continuity. While **Project** alignment can match the required levels of continuity, this setting

cannot create colinearity which is essential to achieving high-end surface quality.

When using the **Project** alignment setting, each influenced CV moves in the direction of the tangent plane normal that is related to a particular CV.

When following the edge of a surface, the CV setup required to create a tangent plane is in a constant state of change. In general terms, this means that the tangent plane on every point along the surface edge is different. During the **Project** alignment procedure, each CV of Surface 1 moves in a different direction.

The image below features five tangent planes. The tangent plane on the far left was created using the circled CVs. Each tangent plane has a normal vector and each CV associated with Surface 1 moves in the direction of the normal vector of the appropriate tangent plane.



Project alignment can be used for aligning surfaces along their edges, as well as, for aligning a surface into the inner portion of another surface.

> DIRECTIONAL

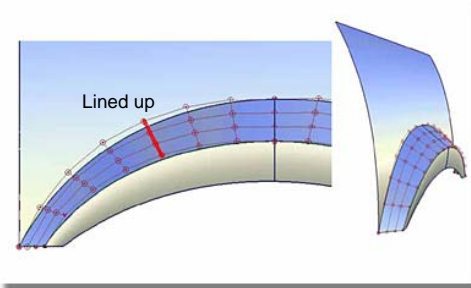
DIRECTIONAL alignment is primarily employed to align Surface 1 to an inner part of the Reference. In using this method, the three previously detailed criteria (Colinearity, Tangent Length Ratios, and **ALIGN BY PROJECT**) are nullified.

By setting the **Alignment Type** option to **DIRECTIONAL**, the movement of CVs are restricted to the direction the user has selected in the option box. As a result, when viewing from the pre-defined direction, the CV distribution will remain the same.

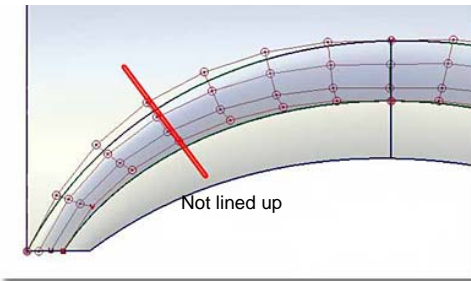
The alignment of Surface 1 to the inner part of the Reference requires that a curve-on-surface be employed as the Reference. Because of the high number of spans (parameterization) associated with a curve-on-surface, **Explicit Control** will have to be

enabled. This ensures that Surface 1 will maintain the same number of degrees and spans that existed in the surface before the execution of the alignment process.

The image below typifies a situation common to automobile design - the wheel opening. With the CVs of the transition surface perfectly lined-up, the goal is to align the transition surface to the side surface by curvature.

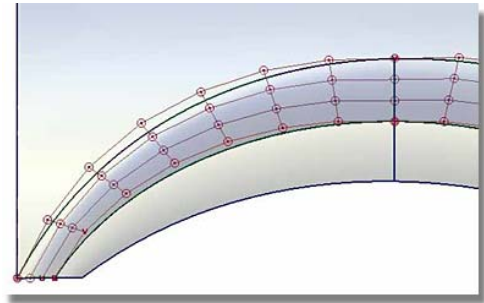


When using the **ALIGN BY PROJECT** setting in the wheel opening scenario, the CVs of the second and third rows move in the direction of the tangent plane associated with each CV which could result in substandard CV distribution as depicted in the image below.



When viewed from the side, the CVs are no longer lined-up. Using the **DEFAULT** alignment setting will produce the same results. In fact, both the **ALIGN BY PROJECT** and **DEFAULT** alignment settings cannot guarantee a strictly radial CV distribution.

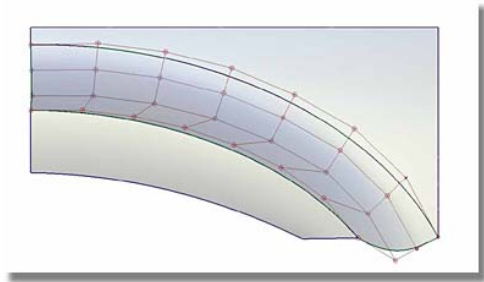
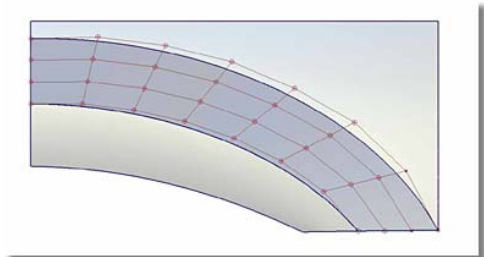
The solution to the wheel opening scenario is to restrict the CV movement to the Y-direction. This can be achieved by using the **DIRECTIONAL** setting.



> **PERPENDICULAR TO EDGE**

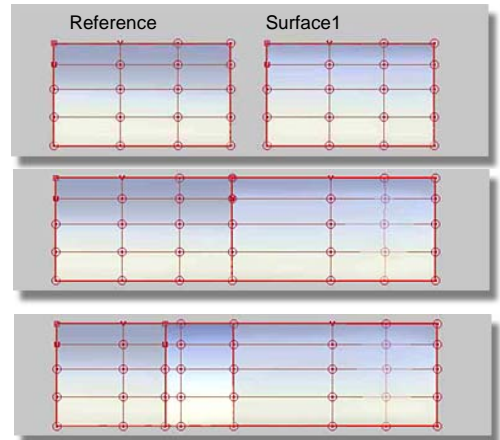
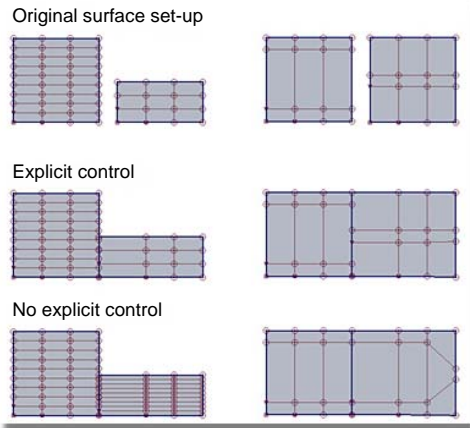
This setting aligns the second and third rows of the surface in a dictated direction. This direction is always oriented 90 degrees to the curve-on-surface in use.

The following images depict the before and after state of a surface when using **PERPENDICULAR TO EDGE** alignment.



> **Explicit Control**

By enabling the **Explicit Control** toggle, the original parameterization of the patch is maintained throughout the alignment procedure. (Parameterization is defined as the number of degrees and spans of a curve, as well as the initial position of the CVs).



Situations that require Explicit Control

- 1 When aligning surfaces with different degrees, span placements, and CV distribution
- 2 When a curve-on-surface is the Reference

This arrangement is most beneficial when constructing conceptual work in which the surfaces are not fixed.

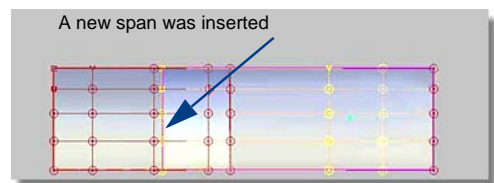
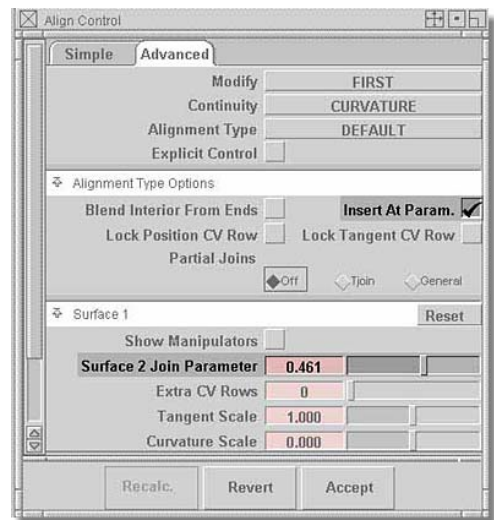
Alignment Type Options

> Blend Interior From Ends

The **Blend Interior From Ends** option is associated with the **Continuity** setting **TANGENT**. When attempting to create curvature, the third CV row responsible for curvature will not be influenced by this option. Instead, this option pressures the second CV row of Surface 1 along a pre-defined line that is an interpolation of the first and the last CVs of the second row of Surface 1.

> Insert At Parameter

The **Insert At Parameter** toggle should be enabled when sliding Surface 1 onto the Reference. Surface 1 can be moved on top of the Reference by using the **Surface 2 Join Parameter** found in the Surface 1 chapter. Enabling the **Insert at Parm** toggle inserts an isoperimetric line at the Reference to help fix the position of Surface 1 on the Reference.



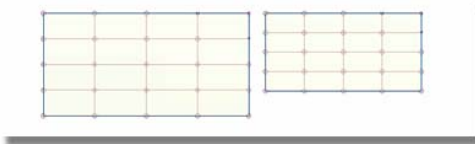
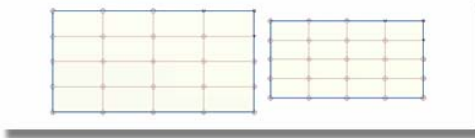
> Partial Joins

Partial Joins involve the management required to align two surfaces whose edges differ in size at the line of connection. The **Partial Joins** option does not influence the **Alignment Type** option.

The two settings used to create partial joins are Tjoin and General.

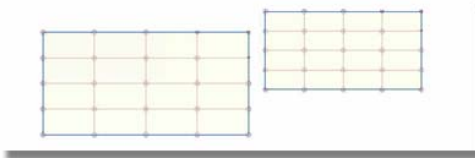
Tjoin

The images below detail situations that must be addressed by the Tjoin setting. The Reference surfaces are on the left.

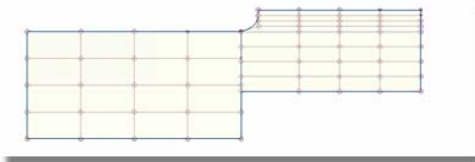


General or Tjoin

The image below shows a situation where both the Tjoin and General settings can be effective.

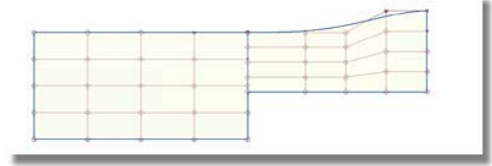


The General setting creates a segment at the point where Surface 1 joins to the corner point of the Reference surface.



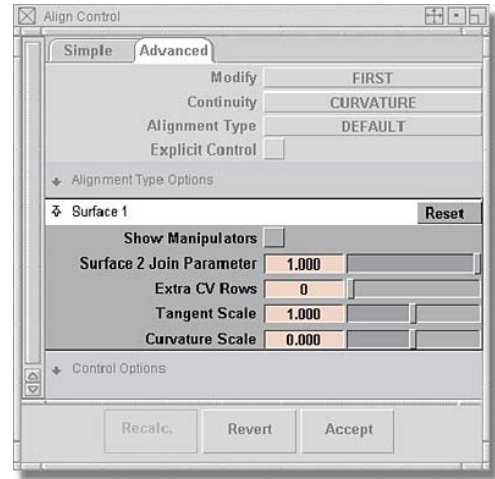
When using the General setting, there are two other options (**Modify Interior Allowed** and **Attach Hardness**) that allow for further refinements to the shape of Surface 1.

The Tjoin setting lines-up the corner of Surface 1 with the Reference surface without creating a new segment.



The Surface 1 chapter

The Surface 1 chapter contains the options used in the management of Hull distribution across Surface 1.



Depending on the selected quality, the influenced row can have a maximum number of 3, but by incorporating extra CV rows, the number of influenced rows can be extended to achieve a smoother CV distribution in the interior of Surface 1. The additional row(s) will be highlighted and moved in keeping with the restrictions of the **Continuity** setting (**POSITION**, **TANGENT**, and **CURVATURE**).

To scale the Hulls, the **Tangent Scale** and **Curvature Scale** sliders are available to the user. To further influence the movement of extra rows, the **Decay Degree** slider can be manipulated.



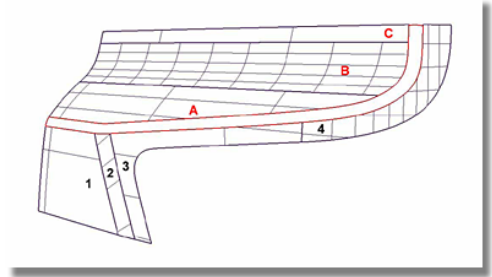
When using the **Decay Degree** slider, it is important to consider that higher numbers will produce less influence on the extra CVs. The **Decay Degree** slider runs on an exponential scale that results in a dramatic decrease in influence as the value is increased in small increments.

Surface Fillet Tool

Basics of surface fillets

The option box associated with the **Surfaces > Surface fillet** tool contains a simple and an advanced mode. In order to master the Fillet tool, it is beneficial to work exclusively in the advanced mode.

The Fillet tool, in general terms, creates a fillet surface between two surface clusters. A surface cluster can include more than one surface.



The Fillet tool requires a tangent continuity between the surfaces of each cluster.

Selection Process

When creating surface fillets, the order of the selection process is crucial.

Selecting surfaces for use with the Fillet tool

- 1 Select the first surface cluster.



SurfaceStudio allows for window selection by dragging a selection window over the surfaces. Located at the center of the selected surfaces, clicking a blue arrow changes the direction of the vector. In general terms, the vector direction specifies where the fillet will be created.

- 2 Confirm the surface selection by clicking the **Accept** button located at the bottom of the screen.
- 3 Select the second surface cluster.



It is possible to drag another selection window over the surfaces. As the window may include surfaces that belong to the first cluster, SurfaceStudio recognizes that they have already been selected. The major vector can be changed in the same manner as the first surface cluster.

- 4 Confirm the second surface selection by clicking the **Accept** button located at the bottom of the screen.

If the selection process was a success, and the options (such as the size of the radii, or the direction of the major normal vectors) are without conflict, the fillet surface is created.

If the fillet surface creation fails, an error message will appear in the Information Line located at the top of the screen. The details of the failure may include an illogical set-up of the major normal vector which can be easily corrected by manipulating the blue arrows.

Construction Type

The **Construction Type** option defines the kind of input required to create the fillet surface. The three settings available in this option are **CONSTANT**, **VARIABLE**, and **CHORDAL**. To create a freeform fillet (blend), choose **Surfaces > Multi-Surface blend > Freeform blend**.

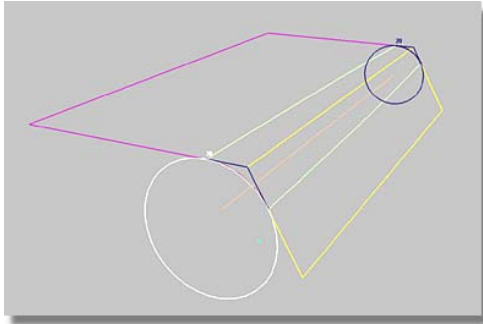
> CONSTANT

This setting requires a radius input to create the fillet surface. The resulting fillet surface has the same radius along the entire surface.

> VARIABLE

This setting also requires a radius input to create the fillet surface. However, the **VARIABLE** setting allows for the possibility of creating a fillet surface that uses multiple radii along the length of the fillet.

A manipulator is available for interactively setting the variable radii.



The manipulator has an orange line and circles that specify the different radii.

Two methods for creating new circles

- 1 Move the cursor onto the orange line. Click the **middle mouse button** to create a new circle and hold down the middle mouse button to move the circle interactively along the orange line.
- 2 Move the cursor onto the orange line. Click the **left mouse button** to create a new circle on the orange line and press the **left mouse button** to change the size of the radius.



In both cases, the new circle is created with the size of the Profile radius.

Methods for modifying existing circles

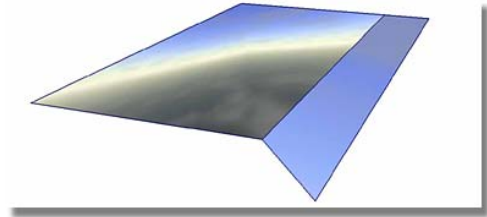
- 1 To remove a circle, press the **Shift** key and click the circle with any mouse button.
- 2 To select a circle, click the circle using the **left mouse button**. Holding down the **left mouse button** changes the radius of the selected circle.
- 3 To move a selected circle, hold down the **middle mouse button**.

> CHORDAL

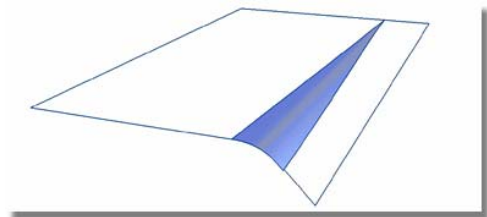
In order to use this setting, specify the distance between the entry lines of the fillet. The distance measurement will remain constant across the entire

fillet and will result in a fillet composed of various radii. The radii are automatically calculated.

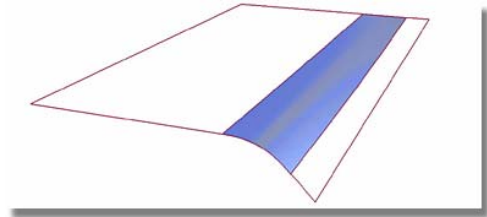
The **CHORDAL** setting is most useful when the continuity between both surface clusters becomes tangent.



In the case shown above, any method that uses pre-defined radii will always create triangle surfaces, as shown below.



As can be seen below, the **CHORDAL** setting maintains a constant distance between the fillet entry lines.

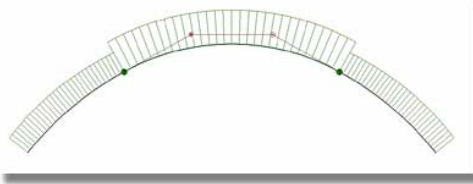


Section Type

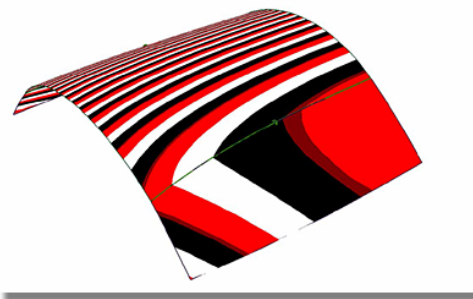
This option defines the shape of the fillet surface. The three main settings available in this option are **CIRCULAR**, **LEAD**, and **CURVATURE**.

> CIRCULAR

This setting creates a fillet surface that features a circular cross-section that is tangent to both surface clusters. **TANGENT Continuity** is maintained with the surfaces on either side.



As shown above, after using the **CIRCULAR** setting a curvature comb reveals a visible curvature break. As depicted in the image below, this curvature break will be reflected in the finished model by an abrupt change in the highlights of the surface.

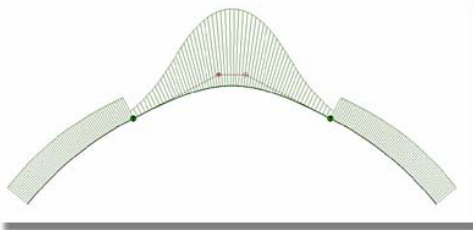


> LEAD

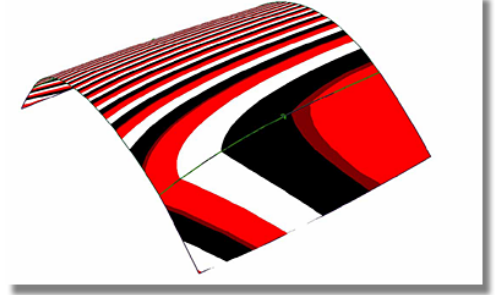
This setting creates a fillet surface that along with the **Center Radius** and **Tangent Offset** options define the point of contact with the inner surfaces. **TANGENT Continuity** is maintained with the surfaces on either side.

The **Center Radius** option defines the radius at the peak of the fillet.

The **Tangent Offset** option defines the contact with the Reference.



As shown by the curvature plot in the above image, the **LEAD** option produces a visible curvature break. But, as depicted in the image below, the curvature results of the **LEAD** option provide for a better highlight than the **CIRCULAR** option.



The **LEAD** setting requires the input of two different radii.

The **Tangent Offset** option associated with the **LEAD** setting specifies the distance between the intersection line of the two sets of surfaces and the contact lines (the lines along which the new fillet surface touches the surfaces on either side). The radius for the contact line and the value for the **Center Radius** option can be input into the **Tangent Offset** option.

The **Center Radius** option associated with the **LEAD** setting specifies the radius at the peak of the fillet.

The **Specify** option associated with the **LEAD** setting has two methods for radii input.

The **KNEE RATIO** setting in the **Specify** option is for detailing the ratio between the **Center Radius** and the **Tangent Offset** distance.

$$\text{KNEE RATIO} = \text{Center Radius} / \text{Tangent Offset}$$

Since the two numbers result from different lead distance measurements, it does not matter in which order they are specified.

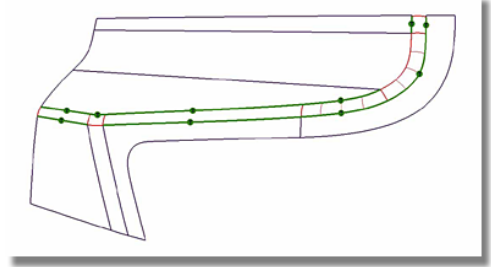
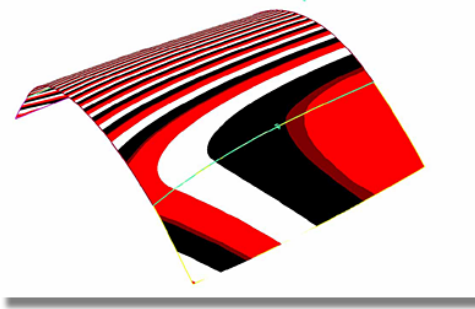
> CURVATURE

The **CURVATURE** setting creates a fillet that has **CURVATURE Continuity** on both sides of the surfaces.



This setting provides optimal continuity. As shown in the image below, a final surface model built with the

CURVATURE setting is not burdened with a visible contact line.



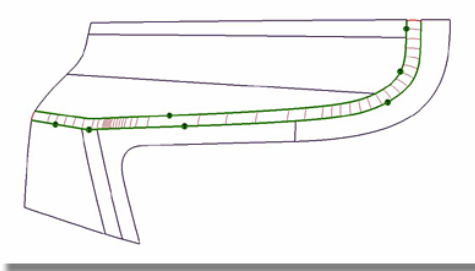
When using the **ONE-PER-BOUNDARY** setting another option is available. The **Single Surface** toggle dictates whether or not the inserted spans at the corresponding boundaries will divide the fillet surface in single pieces. If the **Single Surface** option is not enabled, the fillet surface is created as one object that is sub-divided into separate surfaces.

Span Placement

This option controls the span division within the new fillet surface. There are two settings within this option, **DEFAULT** and **ONE-PER-BOUNDARY**.

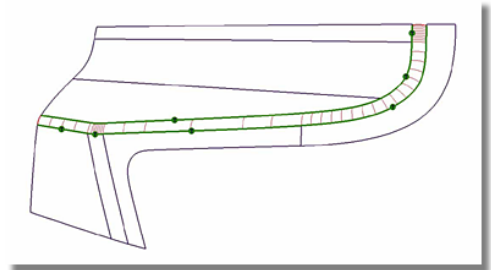
> **DEFAULT**

By using the **DEFAULT** setting, a fillet surface is created with the minimum number of spans required to fix the tolerance. The placement of the spans follows internal mathematical rules that are independent of the surface layouts of both surface clusters.



To achieve an optimal fillet surface comprised of the least number of spans, use the **ONE-PER-BOUNDARY** setting without enabling the **Single Surface** option.

By enabling the **Single Surface** option, a fillet surface is created that is one object consisting of one surface.



> **ONE-PER-BOUNDARY**

By using the **ONE-PER-BOUNDARY** setting, spans are inserted into the fillet surface that correspond to the boundaries of both surface clusters. Additional spans are also inserted into the fillet surface to meet the requirements of the tolerance. As a result, the **ONE-PER-BOUNDARY** setting usually produces less spans than the **DEFAULT** setting.

Undo All

The **Undo All** button is located at the bottom of the Surface Fillet Control box. When creating a fillet surface that requires the incorporation of multiple surfaces, an abundance of geometry could be created such as curve-on-surfaces on each surface cluster or single fillet surface pieces. If the fillet needs to be deleted, it is much easier to select all of the geometry first.

A recommended method for selecting all of the geometry is to reactive the **Fillet** tool by using the **Object edit > Query edit** tool. Once the Surface Fillet Control box has been reactivated, click the **Undo All** button to delete the complete fillet, including any curve-on-surfaces.

Master the Geometry Elements

A detailed comparison of NURBS and Bezier surfaces.

NURBS vs. Bezier Surfaces

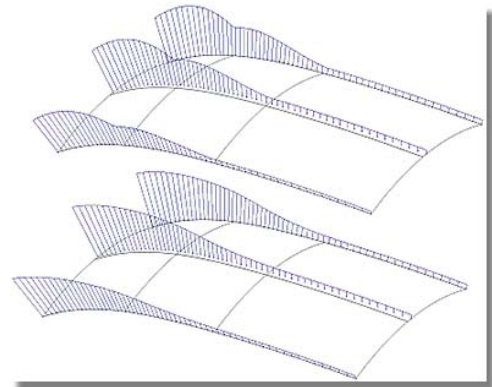
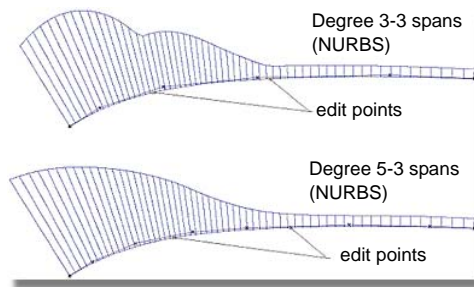
SurfaceStudio has a common mathematical foundation called b-splines that enable SurfaceStudio users to generate NURBS geometry

(that can imply multi segment geometry) and Bezier geometry (single span geometry).

Mathematically, a single segment NURBS surface is equivalent to a single Bezier surface patch. Mathematically, Bezier surfaces are a subset of NURBS.

Addressing Interior Breaks in Continuity

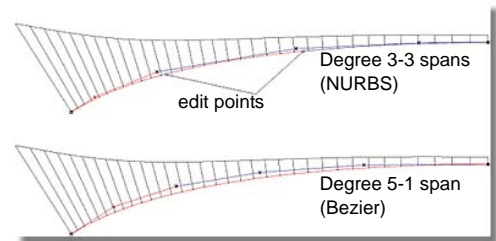
Using curvature diagnostic functions, users can analyze multi-span degree 3 geometry and detect abrupt changes in **G3** curvature.



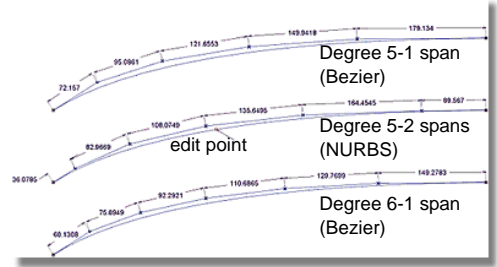
The above image demonstrates the difference in curvature combs when analyzing multi-span degree 3 and degree 5 geometry. The top curve in the above image is a degree 3-3 span curve; notice the abrupt changes in the curvature comb. The lower curve in the above image is a degree 5 curve; the degree 3 curve has been rebuilt to degree 5 without any CV modification. The deviation between the two curves is 0.000 millimeters. The degree 5 curve is just as easy to achieve using SurfaceStudio.

When to use Bezier Surfaces instead of NURBS Geometry

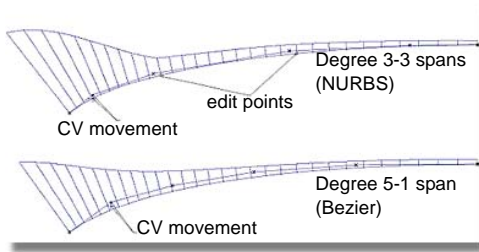
When using Bezier geometry, each CV has an equal effect on the shape of a curve or surface (curvature comb). When using NURBS geometry, a single CV's influence is limited to a local region of the geometry. This local region is referred to as a span or a segment. In NURBS geometry, these segments are linked together mathematically, but each segment can be modified locally.



The above image compares Bezier and NURBS geometry. Each curve has seven CVs, offering an equal amount of shape control. The top curve is a NURBS curve while the lower curve is a Bezier curve. Note the highlighted portions of each line; these are the portions of the curve that will be modified when moving the selected CVs. On the NURBS curve, only a portion of the curve is highlighted whereas the entire curve is highlighted on the Bezier curve. This image demonstrates the difference between NURBS and Bezier segmentation.



As can be seen in the image above, the difference between the curves depicted in the previous image lies in the spacing of the CVs. As a general rule, SurfaceStudio users are encouraged to place more CVs where higher areas of curvature are desired. In the example depicted in the image above, the distribution of CVs found in the middle and bottom curves are the result of two different rebuilding methods that were applied to the top curve. When the top curve was originally created, optimal CV distribution was employed, resulting in a gradual decrease in the distances between CVs.

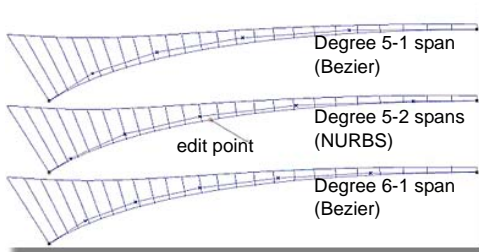


The above image demonstrates the results of a small movement of the CVs selected in the previous image. The CVs on each curve were moved in equal amounts. Notice how the curvature combs have been affected in different manners by the movement of the CVs. While this example suggests that it may be easier to control a curvature comb by using Bezier geometry, SurfaceStudio users are not necessarily required to use Bezier geometry.

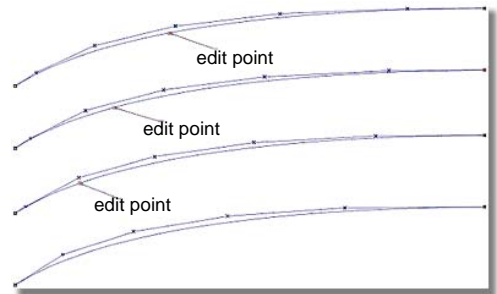
The two rebuilding methods used on the top curve are:

Method 1 (middle curve): rebuild the degree 5 curve to a degree 5-2 span NURBS curve. Note that the spacing of the CVs is no longer decreasing.

Method 2 (bottom curve): rebuild the degree 5 curve to a degree 6 Bezier curve. By increasing the curve's degree, the CV spacing continues to decrease.



In the above image, Bezier and NURBS geometry are further compared. The three curvature combs in the above image depict a degree 5 curve at the top, a degree 5-2 span curve in the middle, and a degree 6 curve at the bottom. The curves are identical in shape, but vary in complexity. The purpose of the above image is to demonstrate that a NURBS curve can have the same curvature characteristics as a Bezier Curve.



The above image demonstrates the insertion of additional spans into a degree 5 curve. When a user inserts a span in an effort to increase control, it can be difficult to anticipate where the new CVs should be located. This "freehand" type of rebuilding can often lead to CVs being placed too close to one another, or cluttered at, or near, the end of the geometry. This uneven CV distribution may result in

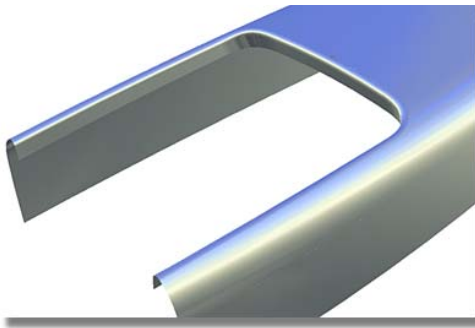
rapid curvature changes when the CVs are modified. The addition of CVs is a measure to help gain more control over curves or surfaces, but the uneven distribution of CVs can, as in this example,

reduce the amount of control. When using SurfaceStudio, instead of adding spans, increase the degree of a curve as the modifications will maintain uniform CV distribution.

When to use NURBS Geometry instead of Bezier Geometry

When two surfaces intersect, the resulting curve (intersection line) can be more complicated than either of the two input surfaces. The reason for the increase in complexity is mathematics. In SurfaceStudio, users set the system tolerances to specify the continuity required along surface boundaries, but to create complex geometric shapes, more control may be required. The shapes produced by Bezier geometry are somewhat limited by the degree value, which in turn, can be limited by the downstream CAD system.

How CAD systems can achieve the required surface boundary tolerances when the degree value can no longer be increased



The image above depicts a complex fillet and flange condition where the main slab surfaces are Bezier surfaces. When the small flanges and fillets are constructed, the system requires more complex shapes (more CVs) to maintain the required tolerance.

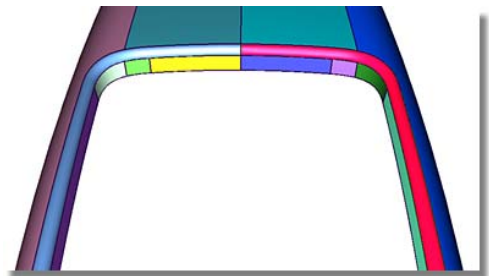


The above image demonstrates how Bezier modeling systems increase the number of CVs while maintaining the tolerance requirements. To approximate complex shapes, additional surfaces are generated. For example, if one degree 5 surface (comprised of 6 CVs) does not meet the edge tolerance, two surfaces are created. The two degree 5 surfaces will have a combined total of 12 CVs along each edge.

Bezier surface (edge)

$$(\text{Degree} + 1) = \# \text{ of CVs}$$

Downstream CAD users can sometimes specify a degree limit. To achieve a required tolerance, CAD systems can create additional surfaces containing the specified degree, until the edge tolerance conditions are met.



As depicted in the image above, NURBS modeling systems can also solve the tolerance requirements. To create complex shapes, spans are added to each surface until the required tolerances have been met.

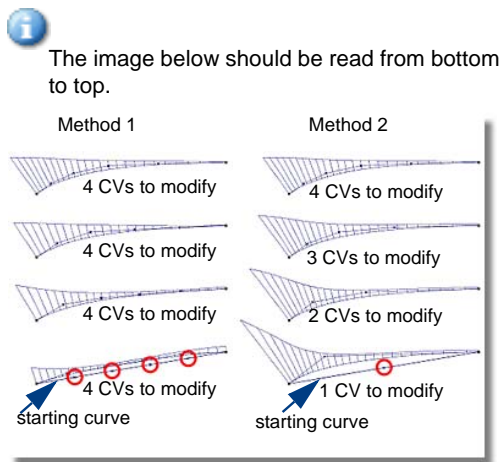
NURBS surface (edge)

$$(\text{Degree} + \# \text{ of spans}) = \# \text{ of CVs}$$

Using the NURBS method, the degree value remains the same while the number of spans increase. The main benefit of this method is that fewer surfaces are required to define complex shapes.

Choosing the Right Curve for the Job

The popular assumption that degree 5 geometry is superior to other degree geometry is partially true. Degree 5 geometry will not produce internal abrupt **G3** changes. But perhaps a better way to look at the advantages of geometric diversity is to consider those shapes other than straight lines and arcs. If users only required parts with straight edges, degree 1 geometry would suffice for all designers. To create more complex shapes, users require higher degrees of geometry, but this does not suggest that all shapes require a degree 5 (or higher) complexity to achieve quality results. There are many techniques that can be employed to create curves in SurfaceStudio. Two of the main methods are shown in the following images.



Method 1

- 1 Create a degree 5 curve between two points.
- 2 Modify the four interior CVs until the required shape is achieved.

Since the four interior CVs are spaced equally in a straight line at the beginning of the procedure, all four interior CVs must be modified in each step to achieve the final shape.

- 3 Use curvature combs to judge the shape of the geometry.

Method 2

- 1 Create a degree 2 curve between two points.
- 2 Modify the middle CV to get the desired shape.
- 3 If the shape cannot be achieved with this simple curve, increase the degree by 1.
- 4 Modify the 2 middle CVs to achieve the desired shape.
- 5 Continue to increase the degree and modify the CVs until the final shape is achieved.



This method tends to move the CVs toward the areas of increased curvature. By increasing the degree by 1, the optimal shape can be defined with the fewest CVs. The degree limit can be based on many issues, one of which is the requirements of downstream CAD software.

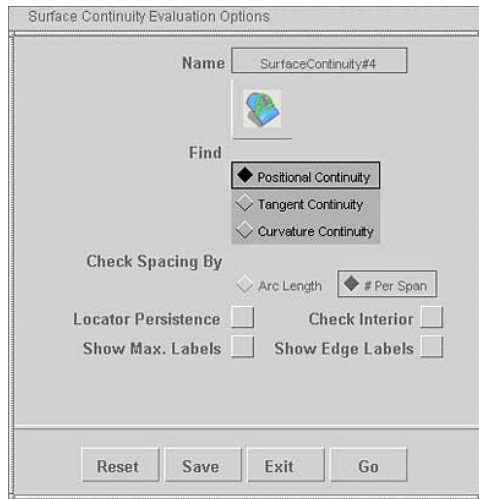
Master Surface Evaluation

A detailed examination of the tools required to perform a global evaluation of the finished model.

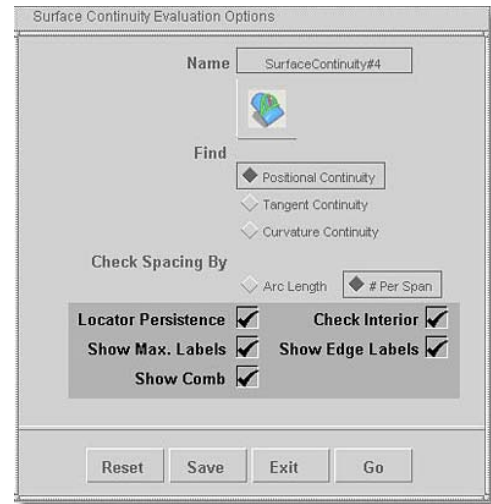
Surface Continuity

When importing or exporting a surface model, check that the model meets the required continuity. The model can be evaluated for all three continuity types (**POSITION**, **TANGENT**, and **CURVATURE**).

The entire model must be selected before an evaluation can be conducted. To begin the evaluation, double-click the **Evaluate > Continuity > Surface continuity** tool icon to produce an option box. The model can be evaluated using the three settings associated with the **Find** option (Positional Continuity, Tangent Continuity, and Curvature Continuity).



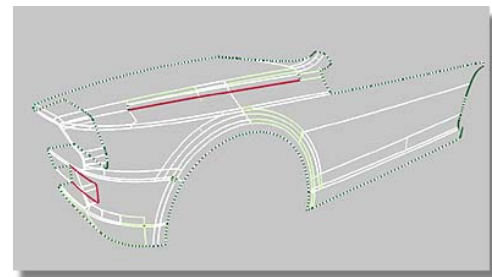
As highlighted in the image below, the Surface Continuity Evaluation Options box allows for the selection of specific errors to be returned by the evaluation process.



The evaluation process is executed via the **Go** button located at the bottom of the options box.

The model is evaluated according to the stated construction tolerances. If there are errors in the model, they are highlighted on the model.

The outline of the model shell appears as a green dotted line. Interior gaps, or Tangent Continuity and Curvature Continuity errors, are highlighted in red.



The diagnostics that depict errors are temporary markers. By selecting the **Pick >**

Nothing tool, the locators disappear. To allow the locators to remain visible, the evaluation must be conducted on individual selections.

When using individual selections, Tangent and Curvature Continuity errors as well as any additional gaps will be highlighted in red. The individual selections must be picked after clicking the **Go** button in the option box.

Model Check

Handling the Check Model Tool

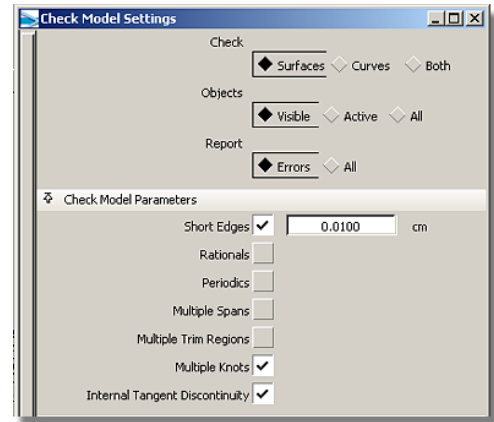
When exporting a model to an external CAD package, special requirements must be addressed in terms of the mathematical behavior of the geometry. The **Evaluate > Check model** tool offers additional capabilities for evaluating the geometry of a model. At the top of the Check Model Settings option box, the **Check**, **Objects** and **Report** options offer settings for refining the organization of the algorithms to be evaluated.

By pressing the Check button at the bottom of the Check Model Settings box, the evaluation process is enabled. The results of this evaluation are populated into the Check Model Results table. Clicking the items listed in the Check Model Results table highlights the corresponding objects in the model scene.

Name	Rational	Periodic	Multiple Knots	Gaps	Multiple Spans	Short Edges	Multiple Trims	Lim Shown
Surface001								
Surface002								
Surface003								
Surface004								
Surface005								
Surface006								
Surface007								
Surface008								
Surface009								
Surface010								
Surface011								
Surface012								
Surface013								
Surface014								
Surface015								
Surface016								
Surface017								
Surface018								
Surface019								
Surface020								
Surface021								
Surface022								
Surface023								
Surface024								
Surface025								
Surface026								
Surface027								
Surface028								
Surface029								
Surface030								

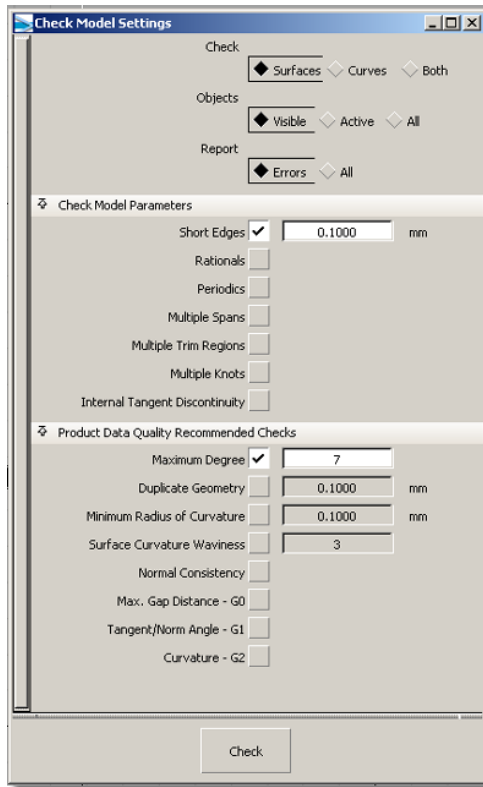
> Multi Knots

Within the Check Model Settings box, under the Check Model Parameters chapter, the model can be evaluated for the presence of multi knots by simply enabling the **Multiple Knots** option. By also enabling the **Internal Tangent Discontinuity** option, tangent breaks are evaluated that occur inside of a surface that contains multi knots.



> Short Edges and Degree

By enabling the **Short Edges** and **Maximum Degree** options found in the Check Model Settings option box, the model can be checked for short edges and geometry exceeding the maximum degree specified. When the **Short Edges** and **Maximum Degree** options are enabled, the fields to the right of their check boxes allow for the manual input of values.



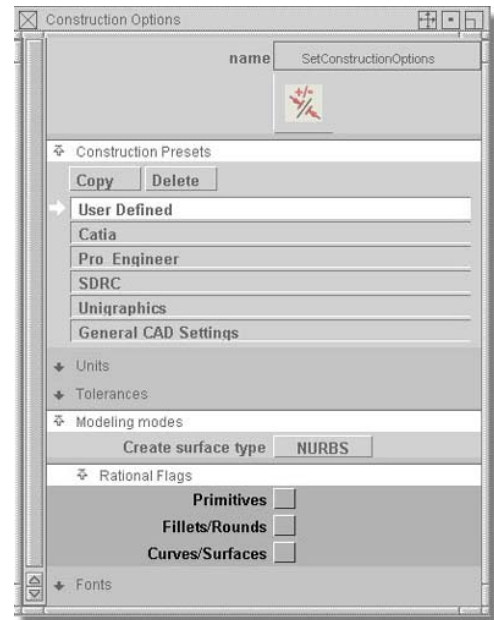
The **Short Edges** evaluation will detect all surfaces that have edges (including trimmed edges) shorter than the distance specified in the tolerance field to the right of the check box. The evaluation of short edges is crucial to ensuring a smooth transition to an external CAD system.

The **Maximum Degree** evaluation option will detect all curves and/or surfaces that have a higher degree than that specified in the field to the right of the check box.

> **Rationals and Periodics**

Some CAD systems experience issues when importing and handling rational geometry. To better facilitate the transition of the model to an external CAD system, the **Periodics** and **Rationals** options are available to the modeler.

There is no method for changing rational geometry into non-rational geometry without losing the shape of the geometry. However, the creation of rational geometry can be avoided by adjusting the options found in the Rational Flags chapter located within the Modeling modes chapter of the **Preferences > Construction options** menu item.



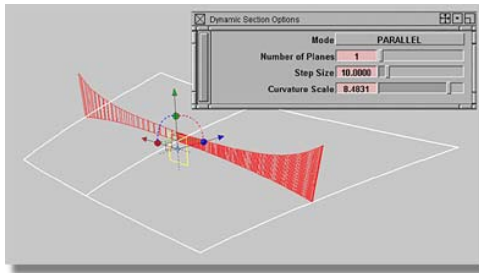
When the three options located within the Rational Flags chapter are not enabled, SurfaceStudio will always create non-rational geometry.

In addition to problems associated with rational geometry, some CAD systems experience issues with the importing and handling of periodic geometry. To address these issues, enable the **Periodics** option found in the Check Model Parameters chapter of the Check Model Settings option box. Surfaces and curves of a revolutionary character may be considered periodic geometry. A method for changing their behavior is to detach the geometry from the items and create a beginning point and an ending point.

Dynamic Section

The **Evaluate > Dynamic Section** tool moves a set of sections through a surface model. (As depicted in the image below, it is possible to add a curvature

plot to the section set). Begin the dynamic evaluation by selecting the entire model.



A manipulator that has the same functional characteristics as the construction plane

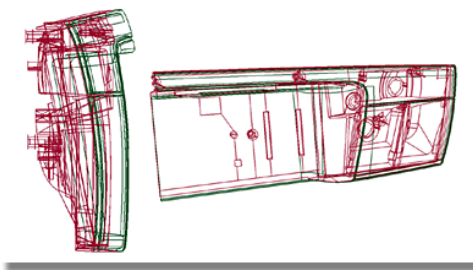
manipulator allows for the modification of the section set. Once the **Dynamic Section** tool has been enabled, two buttons will appear at the bottom of the screen.



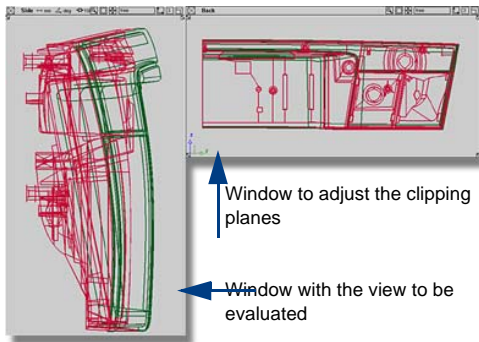
Pressing the **Curvature** button creates a curvature plot on the section set while pressing the **Geom** button temporarily changes the section set into a curve.

Clipping Plane

When attempting to evaluate an intricate model, it can be bothersome to focus on one section set if the model is cluttered with overlapping lines.



The **View > Adjust clipping plane** tool offers a solution for reducing visual clutter by using one window to influence the display depth of another.



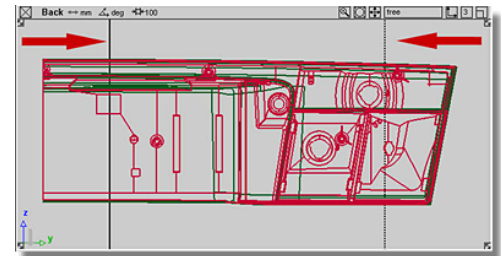
In order to use the **Clipping Plane** tool, there must be a minimum of two windows open in the scene. One window will act as the clipping plane instrument (on the right in the above image) while the other will be the affected window (on the left in the image above).

To begin the clipping plane procedure, make sure that the affected window has the current window focus (bordered in white). After clicking the **Clipping Plane** tool, the focus will then shift to the window that will be used to perform the procedure.

In the window that acts as the clipping instrument, there will be two clipping planes, the near and the far.

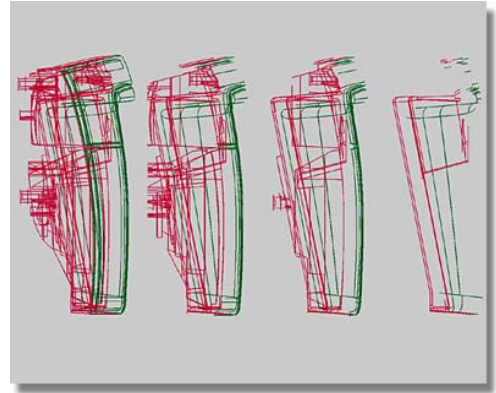
Using the **left mouse button**, click the left-hand edge of the window that is functioning as the clipping instrument. A solid black line appears that represents the near clipping plane.

In order to produce the far clipping plane, use the **right mouse button** to click the right-hand window edge. The far clipping plane is represented by a black dotted line.



To adjust the far clipping plane, drag the **right mouse button**. To adjust the near clipping plane, drag the **left mouse button**. By using a combination of near and far clipping planes, the visibility of the geometry can be manipulated in the affected window.

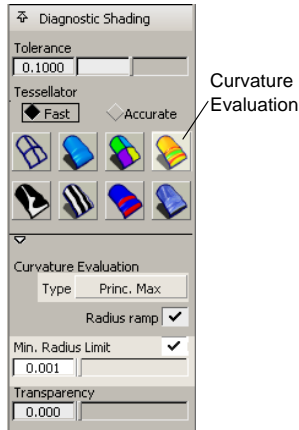
The image below depicts a sequence of views that can be achieved by moving the clipping planes through a model.



Minimum Radii

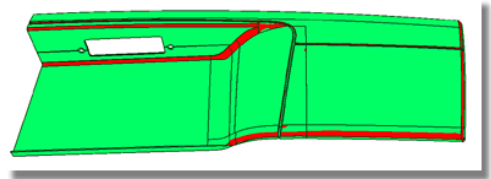
To meet manufacturing requirements, it is necessary to evaluate a surface model for the minimum radii size. All radii that fall below a defined value must be detected.

To evaluate the minimum radii, use the **Curvature Evaluation** shader found in the **Diagnostic Shading** chapter located in the **Control Panel**. By clicking the icon highlighted in the image below, the Surface Evaluation chapter is produced. There are eight settings in the **Type** lister.



The **Princ. Max** setting of the **Type** option shows the **Min. Radius Limit** option. Turning on this option by clicking the checkbox displays a slider that can be used to enter a minimum radius value.

In the image below, the surfaces, or areas of surfaces that fall below the defined minimum radius limit are highlighted in red.



CV Distribution

Because CVs (Control Vertices) represent surfaces and curves, their distribution provides a good method for evaluating the quality of a shape.

Each corner, or end point, features one CV. This lone CV is the smallest representation of a planar surface or line. By adding more CVs, the flexibility of the geometry object is increased.

A shaped object has a CV blanket, or CV net, located above the surface or curve. The CVs are the knot points in the net. A complete row of CVs are referred to as a Hull.

The number of CVs is referred to as the Degree of CVs.

Degree = (total number of CVs in one direction) - 1

The highest Degree that a geometry object can obtain in SurfaceStudio is 9.

CVs can be turned On (+) or Off (-) via the Control Panel after the geometry has been selected.

The appearance of CVs can be altered via the **ObjectDisplay > Draw style** menu item.

To evaluate the distribution of CVs, use the **View > Local Move camera > Azimuth/elevation** tool or

the **View > World Move camera > Dolly** tool in a non-perspective window.

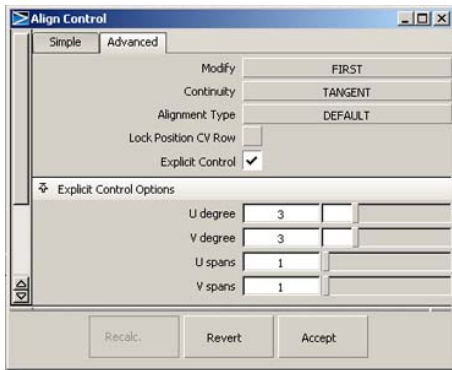
Basic rules of CV distribution

- 1 The CV distribution should represent a smooth clean shape
- 2 The CV distribution should avoid abrupt inflections
- 3 The CV distribution should have a character that follows the shape of the surface
- 4 The CV distribution should be composed of the minimum number of CVs

Span Distribution

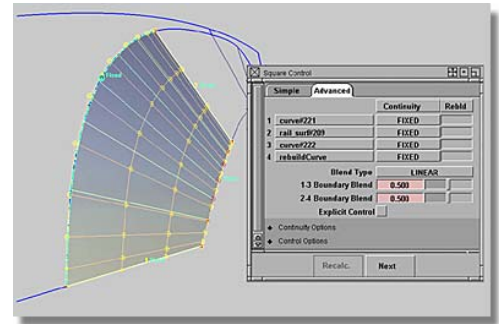
Various tools in SurfaceStudio offer an **Explicit Control** option.

This option allows for the manipulation of the number of spans and the degree of created or modified surfaces. Enabling the **Explicit Control** option produces an Explicit Control Options chapter that regulates the degree and number of spans.



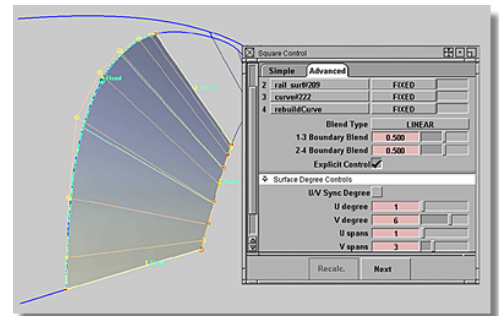
When working without the **Explicit Control** option enabled, SurfaceStudio usually calculates more spans than are necessary. There are, however, some default settings within SurfaceStudio that calculate degree 3 geometry instead of degree 5 when the **Explicit Control** option is not enabled.

The image below shows a square surface that was created without the **Explicit Control** option enabled.

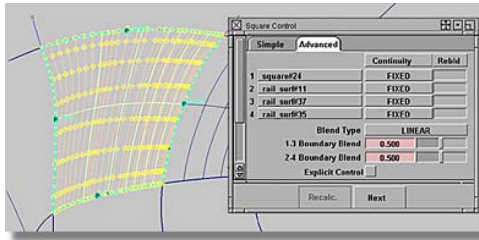


As is often the case, the mathematical complexity of a curve-on-surface unnecessarily increases the number of spans on a created or aligned geometry.

The image below shows the same surfacing situation as the image above, but with the **Explicit Control** option enabled.

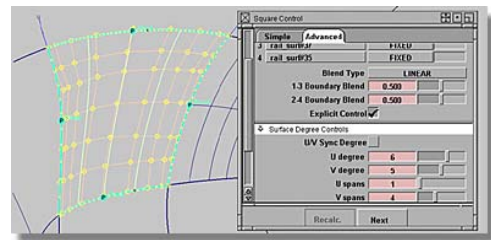


Another benefit of enabling the **Explicit Control** option is the regulation of an even span distribution. The image below shows the span distribution that results from not enabling the **Explicit Control** option.



As can be seen in the image above, the distances between the spans varies, resulting in a span distribution that is not regular.

The image below shows the results of the same surfacing situation as the above image, but with the **Explicit Control** option enabled. As well as decreasing of the number of CVs, the span distribution is of a higher caliber of regularity than the image above.



Diagnostic Shading via the Control Panel

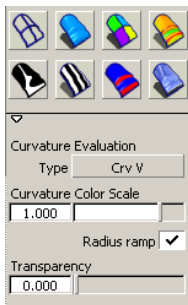
Surface Evaluation

Curvature Diagnostics

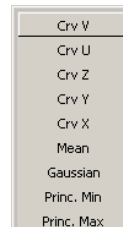
Curvature diagnostics are enabled by clicking the Curvature Evaluation shader icon found in the Diagnostic Shading chapter in the Control Panel.



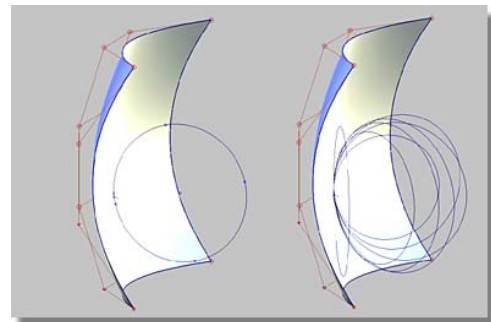
By clicking the highlighted icon in the image above, the Curvature Evaluation chapter is produced. The image below shows the expanded Curvature Evaluation chapter.



A variety of evaluation settings are available by clicking the button associated with the Type option.



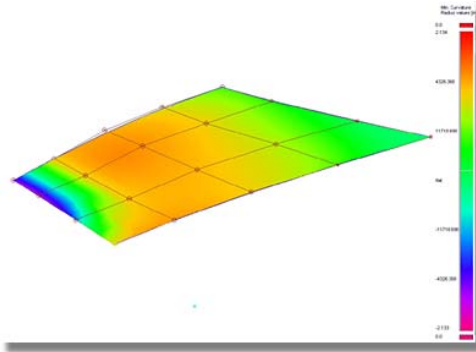
The Curvature Type settings listed in the image above calculate the curvature of surfaces on each point. This calculation measures the diameter of a circle that touches the surface at each point. Points that have a circle with the same diameter will be the same color. The image below demonstrates that each point can have several circles. The evaluation Type settings specify which circles will be used for the calculation.



The **Crv U** and **Crv V** settings orient the circle of each point in the U/V direction.

The **Crv X**, **Crv Y**, and **Crv Z** settings orient the circle of each point in the X, Y, and Z direction.

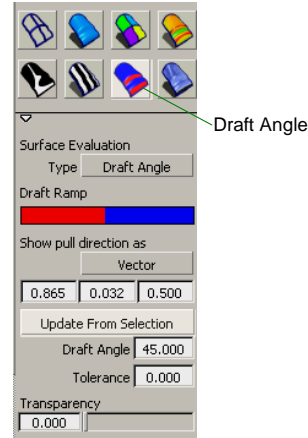
The **Gaussian** setting multiplies the value of the smallest circle and the value of the largest circle. Areas where the surface has inflections or holes can be easily detected by examining the accompanying color bar for negative radius values. The color bar is available at the radius ramp (red - green - blue - purple) that is activated in the Diagnostic Shading chapter located in the Control Panel.



> Draft Angle

Draft Angle shading is enabled by clicking the **Surface Evaluation** shader icon found in the Diagnostic Shading chapter in the Control Panel.

The **Draft Angle** Type setting isolates which parts of a surface are in-draft and which parts are out-of-draft for a specified pull vector and draft angle. The results generated from the **Draft Angle** Type setting depict in-draft points in blue, and out-of-draft points shaded in red. A tolerance region can also be applied to the model, the results of which are shaded in pink. The **Draft Angle** Type settings work best when each normal of the selected surface set points in the same direction, either inwards or outwards.



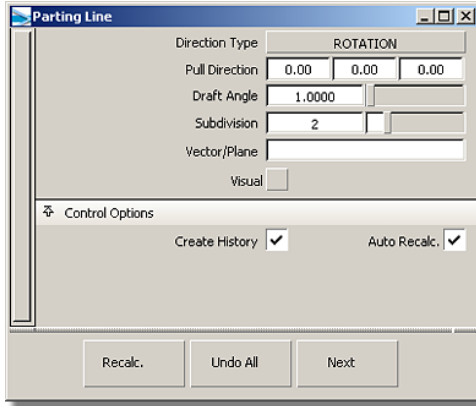
To gain more functionality, use the **Draft Angle** Type setting in the Control Panel in conjunction with the **Evaluate > Parting line** tool.

In order to evaluate how the surface set relates to the pull vector, the pull vector must first be selected. Usually the pull vector is defined by a linear curve. By using the **Construction > Vector** tool, it is possible to create a vector based on the curve. Select the vector, then click the **Update From Selection** button in the Control Panel to use this vector. The **Vector/Rotation** values in the panel are automatically updated.

Another method is to use the **Evaluate > Parting line** tool.

To use the **Parting Line** tool

- 1 Select the surfaces to be evaluated
- 2 Double click the **Evaluate > Parting line** tool's icon to open the option box



3 Set the **Pull Direction** option



The **Pull Direction** option values can be specified via three methods.

Method 1

Direction Type Vector: set the **Direction Type** option to **VECTOR** and type the three vector coordinates into the **Pull Direction** field

Method 2

Direction Type Rotation: set the **Direction Type** option to **ROTATION** and type the three angle values for the vector into the **Pull Direction** option

Method 3

Vector/Plane: in the **Vector/Plane** option, type in the name of a vector, or select a vector in the scene.

Vector/Plane

The optimal method is Method 3 when selecting the pull direction vector directly in the scene. Begin the procedure for Method 3 by first placing the cursor in the field associated with the **Pull Direction** option.

The next step is to select the vector in the scene which will populate the **Pull Direction** option with the vector coordinates.

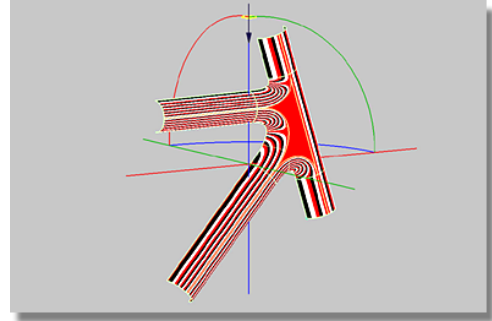
4 Once the **Pull Direction** option has been populated, execute the **Draft Angle** Type setting.

The Draft Angle calculation executed in the Diagnostic Shading chapter of the Control Panel

uses the **Pull Direction** value specified in the **Parting Line** option box.

IsoAngle

The **Evaluate > IsoAngle** tool is employed to evaluate a surface set by highlighting the surface with a light source.



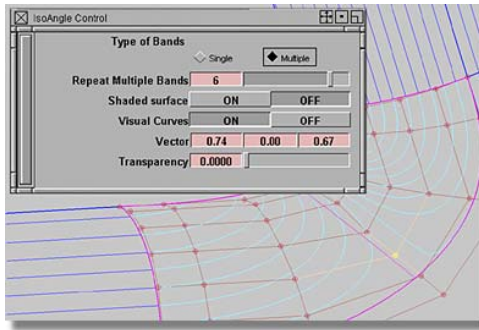
By means of a light source manipulator, surfaces can be evaluated using a variety of lighting arrangements. When compared to the results generated with the Horizontal/Vertical shader located in the Control Panel, the **IsoAngle** tool produces a wider range of evaluation.



There are two isoangle tools in SurfaceStudio. The complete tool resides in the tool palette: **Evaluate > IsoAngle**. The **Iso Angle** shader available in the Control Panel is used for switching the isoangle diagnostics. When using the Iso Angle shader in the Control Panel, the light source manipulator cannot be activated.

To use the **IsoAngle** tool, begin by selecting the surfaces to be evaluated. Then, after opening the option box, the shading and the light source manipulator will appear.

By setting the **Shaded surface** option to **OFF** and **Visual Curves** option to **ON**, the highlights produced by the light source will appear as visual curves. By offering a permanent highlight control, this arrangement is very beneficial when evaluating directly modeled surfaces.



While the Iso Angle shader can switch between shading modes, the shader cannot turn the visual lines on and off.

To remove the visual lines, reselect the surface and set the **Visual Curves** option to **OFF**.

INDEX

Symbols
58, 68

A

adjusting

- rail surfaces 52
- theoretical line 37
- transition surfaces 60

Align tool

- Alignment Type Option 42
- creating a new construction history 41

aligning

- surface with curve-on-surface 68
- two curves 23
- with construction history 69
- Z-scan lines. 22

Angle option

- Draft tool 27

assigning

- layers 55

Auto Align at Surface Corners option

- in Blend curve create tool 75

axes

- manipulator on blend curve 65

B

ball corners 64

- creating 64

- CV modification 69

- direct modeling 67

- guidelines 64

- position continuity 68

Bezier surfaces 64, 95

Blend constraint G2 15

blend curves 13, 15

- Auto Align at Surface Corners option 75

- between surfaces and fillets 51

- blend points 13

- changing continuity types 15

- compared to edit point curves 23

- curvature combs 57

- direct modeling 59

- information window 76

- Knot Spacing option 75

- modifying 48

- modifying to fit to surfaces 52

- position continuity 47

- theoretical line 30

- transition surfaces 46, 56

- using 13

blend points

- display 74

- information on 13

- locators 48

- number of 13

- placement 74

BlendCrv Tools

- Blend curve create 13

- Blend curve edit tangent 16

- Constraint Continuity 15

manipulator 16

C

CAD systems 97

calculations

- reactivate 49

- suspend 48

- suspend rebuilds 49

center line 11

- creating 11

- developing surfaces 26

- establishing 11

- isolating 11

- sketching 9

Center pivot tool 21

click vi

Clipping Plane tool 102

comb scale

- changing values 17

concave 28

connecting

- blend curves to geometry 78

construction history

- Align tool 41

- construction planes 44

- surfaces 37

- while aligning 69

construction planes

- construction history 44

- intersecting with a surface 44

- NURBS 44

- using 44

construction tolerances 3

- solid modeling systems 3

Construction Type

- collar 26

- flange 26

Construction Vector tool 106

continuity 14, 79

- changing blend curve types 15

- curvature 16, 24

- curvature G2 14, 16

- defined 14

- interior breaks 95

- position G0 14, 24

- tangent G1 14, 24

- types 14

- values 14

Control Panel 7

- Cross section tool 26, 44

- loading shelves 7

- Move CV tool 17

- Step size value 39

conventions

- graphic vi

convex 29

correcting

- curvature combs 57

courseware

- CourseWare directory 5
- creating
 - ball corners 64
 - curvature combs 57
 - fillet surfaces 40
 - rail surface 49
 - square surfaces 58
- Cross section tool 26, 44
- Crv U setting 106
- Crv V setting 106
- Crv X setting 106
- Crv Y setting 106
- Crv Z setting 106
- curvature
 - on dynamic sections 101
- curvature combs
 - blend curves 57
 - correcting 57
 - creating 57
 - duplicated curve 57
 - modifying 57
 - optimal state 17
- curvature continuity 14, 24
 - restoring after Align 69
- Curvature Diagnostics 105
- curvature type
 - Geometric setting 79
 - Parametric setting 79
- Curve curvature tool 57
- Curve Edit > Curve planarize 29
- Curve Edit > Fit curve 12
- curve snapping 46
- curves
 - aligning two curves 23
 - as framework for creating surfaces 57
 - checking curvature 16, 21
 - correcting 51
 - curve snapping 24, 46
 - cutting curves using reference geometry 46
 - direct modeling 17, 24
 - extending 33
 - fitting across the Y0 plane 18, 19
 - increasing CVs 20
 - new, with edit points 20
 - patch layouts 57
 - planarizing 30
 - snapping to a pre-defined point 58
 - tips for edit points 22
 - undo extensions 34
 - using edit point curves 22
- curves-on-surface
 - fillet surfaces 45
 - isoparametric directions 45
 - Trim Type option 71
 - trimming 71
- CV distribution 12, 60
 - modification method 1 15
 - modification method 2 15
 - NURBS 44
 - Rebuild option 63
- CVs
 - displaying 13
 - effect of manipulator on blend curves 16
 - increasing 20
 - modifying on ball corners 69
 - modifying when fitting transition surfaces 60
 - Move CV tool 17
 - moving in non-proportional scale 21
 - moving in the Z-direction 20
 - selecting 59
- D
- data input types
 - completed model modification 4
 - sketches & packages 4
 - sorted data 4
 - surface modeling 4
- degree
 - edit point curves 38
 - increasing 35, 60
 - maximum number of CVs 60
 - textbox 20
- deleting
 - all locators 18
- deviation
 - between surfaces and scan lines 40
- direct modeling
 - ball corners 67
 - blend curves 59
 - curves 17, 24
 - surfaces 28
- Direction Type option
 - for Parting Line tool 107
- directional constraint
 - on blend curves 77
- directory
 - wire files 5
- Display options
 - view all CVs 13
- displaying
 - blend points 74
- distribution
 - CV 12
 - hull 12
- double-click vi
- draft angle
 - shading 106
- Draft tool
 - Angle option 27
 - creating new surfaces 27
- drafting
 - surfaces 34
- drag vi
- duplicated curve
 - curvature combs 57
- Dynamic Section tool 101
- E
- edges
 - shaping 50
- Edit > Duplicate > Mirror 20
- edit point curves
 - compared to blend curves 23
 - degree 3 38
 - increasing degree value 38
 - new curves 20
 - tips 22
 - using 22

- edit tangent
 - manipulator 16
- editing
 - tangent on blend curves 36
- Evaluate > IsoAngle 66
- Explicit Control 104
 - in Square 66
- extending
 - curves 33
 - theoretical line 33
- F
- files
 - opening 5
 - organizing 5
 - wire 5
- fillet surfaces
 - blend curves 51
 - creating 40
 - curves-on-surface 45
 - isoparametric curves 56
 - Radius option 40
- flange surfaces 26
- G
- G0 14, 24
- G1 14, 24
- G2 14, 24
- G3
 - Internal Abrupt Changes 98
- Gaussian curvature
 - in Diagnostic Shading 106
- Geom button 101
- geometric curvature
 - on blend curves 75, 79
- geometry
 - cutting curves 46
- Geometry option
 - NURBS as cross sections 44
- Geometry setting
 - interpolation on blend curves 77
- graphic conventions vi
- H
- history
 - construction history 37
- hot keys
 - Viewing Panel 56
- hulls
 - changing the theoretical line 41
 - displaying 13
 - distribution 12
- I
- icons
 - Viewing Panel 22
- increasing
 - degree values 35, 60
- Information Window
 - for blend curves 76
- interior breaks in continuity 95
- interpolation
 - Direction setting, on blend curves 77
 - Geometry setting, on blend curves 77
 - Location setting, on blend curves 77
 - on blend curves 77
- introduction
 - Foundations of Surface Modeling 1
- iso-angle
 - shading surfaces with map of 108
- IsoAngle tool 66, 107
- Shaded surface option 107
- Visual Curves option 108
- isolating
 - center line 11
- isoparametric curves
 - fillet surfaces 56
- K
- key factors
 - adjusting rail surfaces 52
 - manipulating curves 17
 - surface modeling 1
- Knot Spacing option
 - in Blend curve create tool 75
- L
- layers
 - assigning 18, 55
 - making visible/invisible 11, 18
 - new 18
- loading
 - files 5
 - shelves 7
- Location setting
 - on blend curves 77
- locators
 - blend points 48
 - Curve curvature tool 21, 57
 - Deviation tool 16
 - measuring curve-to-curve 15
- Look at
 - tool 11
- M
- magnet snap 35
- manipulating
 - curves, key factors 17
- manipulator
 - blend curve axes 65
 - CV modification on blend curves 16
 - edit tangent on blend curves 16
- marking menus
 - loading 7
- measurements
 - locators 15
- minimum radius
 - curvature evaluation shader 103
- Mirror Across option 20
- mirroring 20
 - X-scan lines 18
- model vi
- models 3
- modification
 - blend curves 48
- modifying
 - curvature combs 57
- N
- non-proportional scaling

- CV movement 21
- NURBS 95
 - construction plane 44
 - CV distribution 44
 - geometry 44
- O
- Object Edit > Align > Align 22
- Object edit > Align > Symmetry Plane Align 28
- Object edit > Patch precision 45
- Object edit > Query edit 15
- ObjectDisplay > Control 7
- ObjectDisplay > Draw style 8
- ObjectDisplay > Hide Unselected 11, 19, 22
- ObjectDisplay > Invisible 41
- ObjectDisplay > Visible 11, 18
- objects
 - view all CVs 13
- Open command
 - opening a wire file 5
- opening files
 - basics 5
 - wire files 5
- organizing
 - files 5
- orthogonal window
 - Project tool 38
- overview
 - SurfaceStudio tutorials v
 - theoretical model 27
- P
- parametric curvature
 - on blend curves 75
- parametric setting
 - blend curves 79
- parting line
 - tool 106
- patch layouts 25
 - curves 57
- patch precision
 - tool 45
- Pick tools, using
 - Component tool 11
 - Nothing tool 15
 - Object tool 11
 - Point Types tool 14
- pickable
 - layers 16
- planar characteristics
 - theoretical line 29, 42
- planarize 29, 30
- Planarize tool
 - Default Projection Plane option 42
 - Keep Originals option 42
- position continuity 14, 24
 - ball corners 68
 - blend curves 47
- Preferences
 - Construction options 7
 - User options 8
- Princ. Max setting 103
- Project normal tool 69
 - ball corners 69
- Project tool
 - orthogonal window 38
- projects 6
- proximity to scan line 15
- Q
- quality 3
- quality levels
 - surface modeling 3
- quality types 3
 - surface modeling 3
- Query Edit tool 15
 - hiding curves-on-surface 58
 - using 50
- R
- Radius option
 - fillet surfaces 40
- Rail surface tool
 - creating transition surfaces 47
 - generation curves 43
 - rail curves 43
 - using 43
- rail surfaces
 - adjusting 52
 - creating 49
 - key factors for adjusting 52
- reactivate
 - calculations 49
- reactivating
 - option box 15
- Rebuild option
 - CV distribution 63
- Reference 16
- reshaping
 - square surfaces 39
- restoring
 - curvature continuity after Align 69
- Rotation setting 107
- S
- Samples
 - changing values 17
- saved data
 - file organization 5
 - loading 4
- scan lines
 - deviation from surfaces 40
 - proximity to blend curve 15
 - view all 11
- scene vi
- selecting
 - CVs 59
- Set State
 - Pickable menu item 16
 - Reference menu item 16
- Shaded surface option 107
- shape of an edge 50
 - trimming the surface 45
- shelves
 - loading 7
- single span spacing 64
- sketching
 - center line 9
- slide 17, 21, 24

- snapping
 - curves to a pre-defined point 58
- solid modeling systems
 - construction tolerances 3
- sorted data
 - data input types 4
- Span Distribution
 - Explicit Control 104
- square surfaces
 - creating 36, 58
 - options 39
 - reshaping 39
- stages 6
- Step size 39
- Surface Evaluation
 - curvature type settings 105
- Surface Evaluation chapter 105
- Type option
 - Crv U setting 106
 - Crv V setting 106
 - Crv X setting 106
 - Crv Y setting 106
 - Crv Z setting 106
 - Draft Angle setting 106
 - Gaussian setting 106
 - Princ. Max setting 103
- Surface Evaluation tool
 - direction type for Parting Line tool
 - Vector setting 107
 - Direction Type option
 - Rotation setting 107
 - Vector setting 107
 - Pull Direction option 107
 - Vector/Plane option 107
- surface modeler
 - relationship to designer 4
- surface modeling 3
 - advanced 72
 - data input types 4
 - key factors 1
 - quality levels 3
 - three defining questions 3
 - traditional 9
- Surfaces
 - Draft tool 26
- surfaces
 - aligning with curves-on-surface 68
 - blend curves 51
 - boundary surfaces 39
 - changing the shape of an edge 45
 - changing the type 35
 - construction history 37
 - creating a square surface 36
 - deviation from scan lines 40
 - direct modeling 28
 - drafting a surface 34
 - fillet surfaces 40
 - increasing degree of 27
 - intersecting with a construction plane 44
 - key factors in making corrections 41
 - modifying blend curves 52
 - transition surfaces 38
 - using the Draft tool 27
- SurfaceStudio
 - about tutorials v
 - construction tolerances 3
 - SurfaceStudio tutorials
 - graphic conventions vi
 - overview v
 - prerequisites vi
 - suspend
 - calculations 48
 - suspending rebuilds 49
 - Symmetry Plane Align tool 28
 - Project for Position option 28

T

- tangent continuity 14, 24
- Tangent type 78
- textbox
 - degree 20
- theoretical line
 - adjusting 37
 - best practices 30
 - blend curves 30
 - changing by moving Hulls 41
 - concave 28
 - convex 29
 - criteria 29
 - definition 29
 - examining 28
 - extending 33
 - lost planar characteristics 42
 - planar characteristics 29
 - solutions to meet criteria 29
 - viewing 28
- theoretical model
 - overview 27
 - traditional 9

Tools

- BlendCrv Tools > Blend curve create 75
- BlendCrv Tools > Blend curve edit tangent 74
- BlendCrv Tools > Blend curve planarize 75
- BlendCrv Tools > Constraint Interpolation Direction >
 - Blend constraint interp geometry 77
- Construction > Vector 106
- Evaluate > Dynamic Section 101
- Evaluate > IsoAngle 107
- Evaluate > Parting line 106
- IsoAngle 107
- Object Edit > Align 77
- Pick > Point Types > Blend point 74
- View > Adjust clipping plane 102

Transform

- Local tools 21

transition surfaces 38

- adjusting 60
- blend curves 56
- modifying CVs 60
- Rail surface tool 47
 - using blend curves to define edges 46

Trim Type

- curves on surface 58
- off 58

Trim Type option

- curves-on-surface 71

trimming

- curves-on surface 71

- surfaces that cross the Y0 plane 71
- Type option
 - in Curvature diagnostics 105

U

- using
 - blend curves 13
 - construction planes 44
 - Cross section tool 26
 - Draft tool 26
 - edit point curves 22
 - Patch precision tool 45
 - Query Edit tool 50
 - Rail surface tool 43
 - Viewing Panel 22

V

- Vector setting 107
- Vector/Plane option 107
- View
 - Look at tool 11
- view
 - all scan lines 11
- viewing
 - theoretical line 28
- Viewing Panel
 - hot keys 56
 - icons 22
 - using 8, 22
- Visible
 - Layers 11, 18
- visible
 - making objects 11, 18
- Visual Curves option 108

W

- Windows
 - Information 14, 16, 17
- wire files
 - directory 5
 - files 5
 - opening 5

X

- X-scan lines
 - mirroring 18

Y

- Y0 plane
 - curves 18, 19
 - trimming surfaces 71

Z

- Z-direction
 - CV movement 20
- Z-scan lines
 - aligning 22