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Mastercam 2020 Handbook Volume 2

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This document requires Mastercam Mill 3D.

TABLE OF CONTENT

Introduction To 3D Workspace **7**

Splines **37**

Surface Modeling **67**

Surface Roughing Machining **141**

Surface Finish Machining **195**

Surface High Speed Machining **217**

Mold Project **273**

Prototype Project **285**

Legend

CONVENTIONS

Key words and Mastercam menu items are shown in bold the first time they are used. Columns on the outside edges of each page and note pages at the end of each chapter provide ample space for taking notes.

Useful tips, recommended settings, best practices, and detailed instruction on the most important features are included when possible.

Extra credit exercises are included on the student CD in PDF format. These will help build your skill to a higher level.

TERMS

The following terms are used throughout this book.

- **Left Click** means to click once on the left mouse button.
- **Click** means the same as left click.
- **Right Click** means to click once on the right mouse button.
- **Scroll** means to roll the mouse scroll wheel, or move the scroll index in a list.
- **Options** are Mastercam functions selected from the main menu.
- **Enter** means to select the <Enter> key on your computer keyboard.
- **Press** means to press on a keyboard key.
- **Choose** means to select a menu option or button.
- **Open/Close** means to open or close a dialog or information box.
- **Dialog Box** is a window that opens to allow for the input of information and the setting of defaults.
- **Panel** is a window that is locked and opens to allow for the input of information and the setting of defaults.
- **Drop Down/Flyout Menus** are menus that expand down, left, right, or up, to reveal more menu lists.
- A **Function** is the same as a menu option or command.
- **Help** means the Mastercam help files loaded with your software.

3 Surface Modeling

OBJECTIVES

This chapter shows how to model parts using surfaces. Upon completion of this chapter, you should be able to do the following:

- Understand the difference between wireframe and surface geometry.
- Understand common surface definitions.
- Identify and create basic surfaces including Ruled, Lofted, Revolved, and Draft.
- Recognize and create advanced surfaces including Swept, Net, Fence, Trim, Fillet, and Offset surfaces.
- Create surfaces that blend plane, curve, or other surfaces.
- Recognize which surface type(s) are suitable given the wireframe geometry and part feature requirements.
- Trim surfaces to a curve, plane, or other surfaces.
- Extend split and un-trim surfaces.
- Remove trim surface boundaries and fill holes in surfaces.

INTRODUCTION

Wireframe geometry consists of lines, arcs, and splines. These entities describe only the edges of the part. They contain no information about what lies on the faces of the part between the edges.

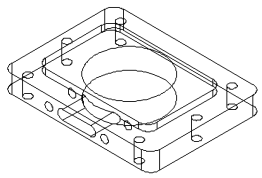
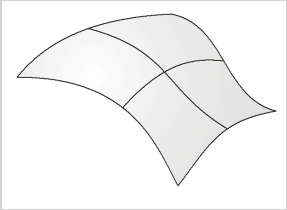
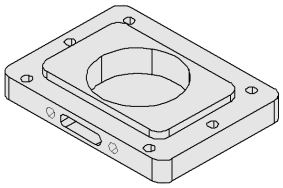
To illustrate, use **Analyze Dynamic** and select the edge geometry of any 3D wireframe part. As you drag the mouse along the wireframe edges, the system displays coordinates. Clicking on the faces of the part fails to select the face and provides no geometry information.

While wireframe geometry includes enough information to model and machine 2D parts, more complex ones, especially those with complex and organic shapes, require more info.. These parts need information about every point that lies on every face of the part. Surfaces and Solids include face information required to model and machine these complex 3D shapes.

CAD GEOMETRY TYPES

There are three types of geometry used by CAD/CAM software:

- Wireframe.
- Surface.
- Solids.

Geometry Type	Description
Wireframe 	• Wireframe geometry consists of curves (lines, arcs, points and splines) and points. • Wireframe geometry includes information only about the edges of a part. • Wireframe models cannot be shaded. • Wireframe geometry is adequate to model and machine most prismatic or "2-1/2D" parts -where all contours exist in flat planes.
Surfaces 	• A surface can be thought of as an infinitely thin shell stretched over a wireframe. • Surfaces can have a 3D shape with length and breadth, but they have no thickness. • Surface geometry includes information about the faces and edges of a part. • There are many types of surfaces; each suited to model a specific type of shape. • Surfaces are used to model complex, free form (organic) shapes common in the automotive, aircraft, mold, and consumer goods industries.
Solids 	• Solids contain information about the edges, faces, and interior of the part. • Most mechanical parts are now designed using Solid Modeling software, like Mastercam Solids®, SolidWorks®, SolidEdge®, ProEngineer®, and others. • Solids are able to model many parts, but some highly sculpted shapes, like car bodies, are best modeled using surfaces. • All Solids start with profiles of wireframe geometry.

SURFACE TERMS

Surfaces begin with wireframe geometry: lines, arcs, splines and points. These entities form profiles, or curves, referred to as **Drive Curves**. Depending on the surface type and shape, one, two or more drive curves may be required to define a surface. These curves are revolved, swept, or otherwise used to create the surface.

With some surface types, drive curves are referred to as running in the **Along** or **Across** direction, depending on whether they run along or across the predominate shape of the part.

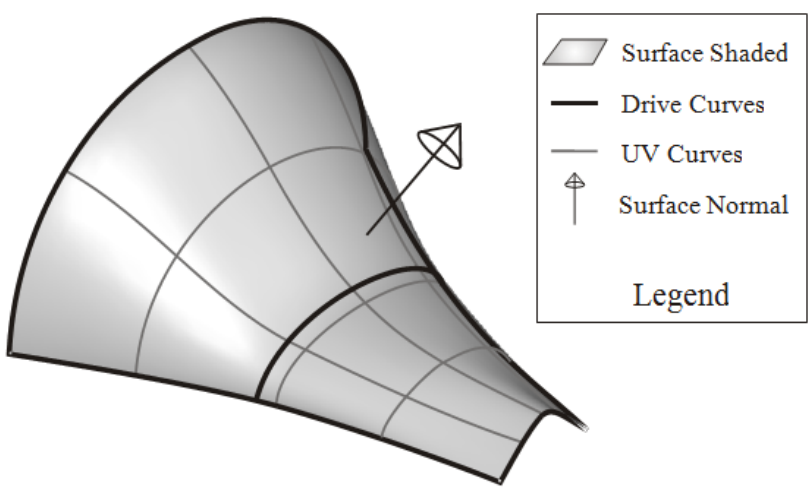
UV curves are curves that run along and across the face of the surface at regular intervals. UV lines are not geometric entities. They cannot be selected for any purpose. They are simply used to help visualize the shape of the surface when shading is turned off. The density, or number of UV lines per surface, can be set for each surface before it is created.

A **surface normal** is a vector that points away from the surface at a 90-degree angle at any particular point on the surface. The direction of the normal can be, and often is, different for every position on the surface. The surface normal is used for certain surface creation, manipulation, and machining operations.

All surfaces can be thought of as having two sides; one that the normal points away from and the opposite side. When shading is not active, the normal side is colored. The opposite side is dull gray.

The surface normal can be displayed using **Analyze Dynamic**. The normal can be flipped from one side to the other using the **Surfaces** tab, in the **Normals** group, **Set** or **Change** functions.

The following illustration shows all common surface terminology.



Surface Terms

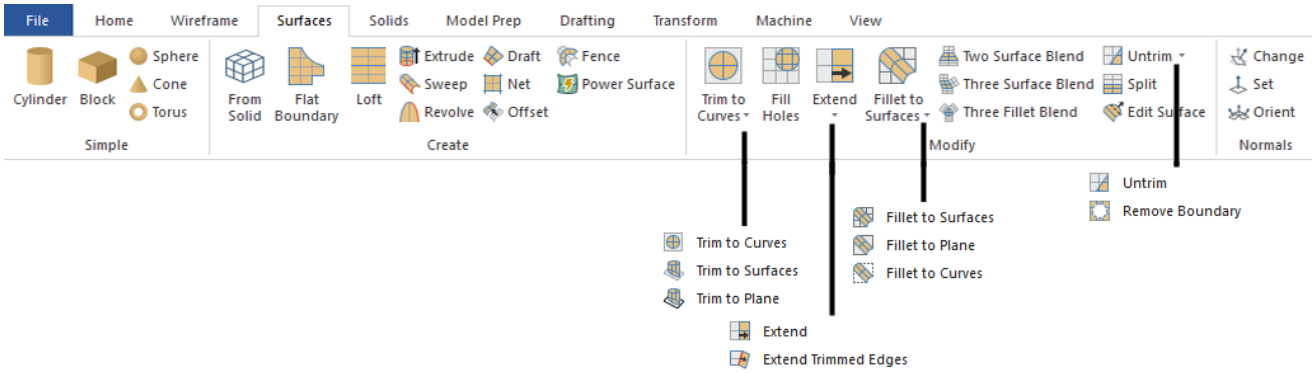
Item	Definition
Drive Curves	Curves used to define the surface.
UV Curves	Used to help visualize the shape of the surface when shading is not active. UV lines are not selectable geometry, but are for display only.
Surface Normal	A vector that points away from the surface at a 90 degree angle all around at any particular point on the surface.
Shading	Shading provides a photorealistic rendering of surface and solid models. It can be turned on/off using Alt+S or the VIEW tab and the Appearance group.
Translucent	A shading mode that allows you to partially see through the shaded object (Ctrl+T).

SURFACE TYPES

Many different types of surfaces have been developed. Each uses a different mathematical model to describe a certain type of shape. Surfaces may have different wireframe geometry requirements and offer relative strengths and weaknesses compared to other surface types. While some shapes can be modeled using different types of surfaces, often only one is best suited for that shape.

Recognizing which surface to use in a given situation, and how to build that surface, is a skill. This skill is developed by first understanding each surface type, its potential applications, and its relative strengths and weaknesses. It takes practice to develop an eye to recognizing which surfaces to use and to acquire the skills needed to create them.

Surfaces supported by Mastercam are shown in the ribbon below.

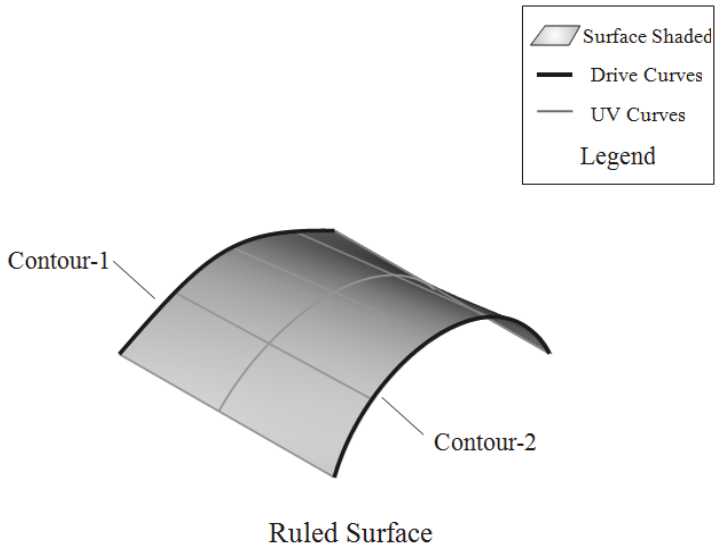


RULED SURFACE

Ruled surfaces are created by linearly blending between two or more contours. Think of this as making the shape by creating evenly spaced lines between the two curves.

These curves can be made up of lines, arcs or splines. Most ruled surfaces use two curves to define the surface. Notice that the UV curves along the ruled surface are linear as shown in Figure: 1.

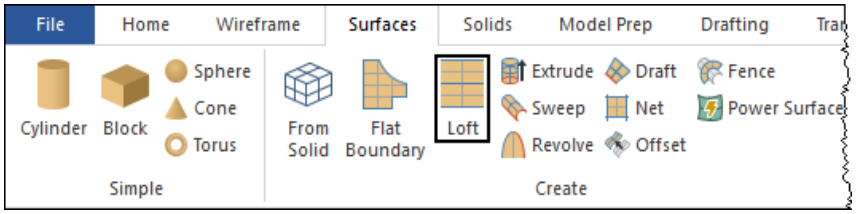
Figure: 1



Consider using a **Ruled surface** to model a shape that could be formed by drawing equally spaced lines between two or more curves.

Follow the steps below to create a simple ruled surface. This example uses the file, Ruled-1.MCAM, which is included on your student CD.

♦ **Step 1:** Select the **Surfaces** tab and from the **Create** group, select **Loft** function.



♦ **Step 2:** Select single in the **Chaining** dialog box and chain Contour 1 and then Contour 2 as shown in Figure: 2. Be sure to pick the curves from the same side so they chain in the same direction or the surface will be twisted as shown in Figure: 3. Press **OK** to exit the **Chaining** dialog box and then select **OK**.

Figure: 2

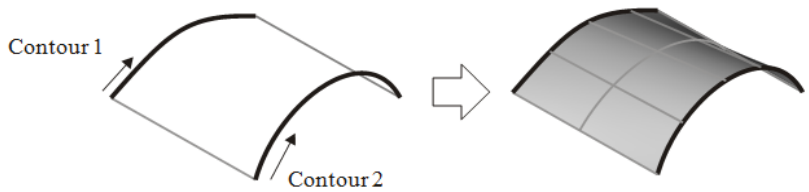
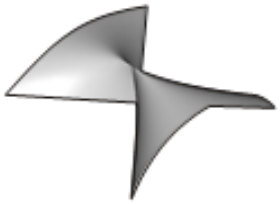
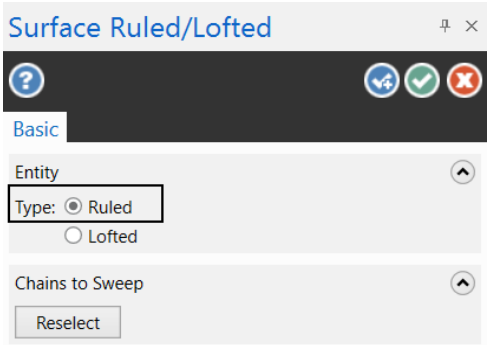


Figure: 3



♦ **Step 3:** In the **Surface Ruled/Lofted** panel, enable **Ruled**.



RULES AND SUGGESTIONS FOR RULED SURFACES

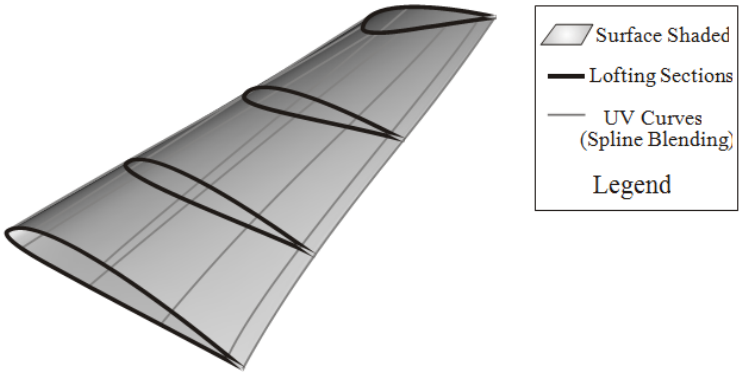
- Always select both drive curves in the same direction. If you select in opposite directions, the surface will be twisted.
- Turn shading on to make it easier to see any errors in the surface.
- Very complex drive curves can cause problems creating the surface. Consider using partial chains to model the shape with two or more ruled surfaces instead of one. In other words, create the shape using several simple surfaces rather than one complex surface.
- Sharp corners in drive curves will sometimes be ignored. Mastercam will display a warning in this case. Consider creating the shape using multiple ruled surfaces or using the Chaining Option, Sync mode. Sometimes putting a small fillet radius (0.001-0.005 inches) on sharp corners will cause the surface to transition smoothly along the curve. Sync mode is covered under Draft Surfaces in this chapter.

LOFTED SURFACE

A **Lofted surface** is similar to a **Ruled surface** except blending between the curves uses splines instead of lines. This example uses the file, LOFTWING.MCAM. This creates a surface that flows smoothly between multiple curves.

Lofted surfaces are used extensively in the boat building and aircraft industry. Examples of parts that use lofted surfaces include wings, propellers, turbine blades, and boat hulls.

Lofted surfaces have three or more drive curves, called **Lofting Sections** or **Lofting Stations**, which are usually parallel to each other as shown in. A lofted surface with only two drive curves would be the same as a ruled surface, since there would be only two node points on the blending splines, making them linear.



Lofted Surface

Consider using a **Lofted surface** when the drive curves are cross sections of the resulting shape, and the shape can be formed by blending splines equally between these sections.

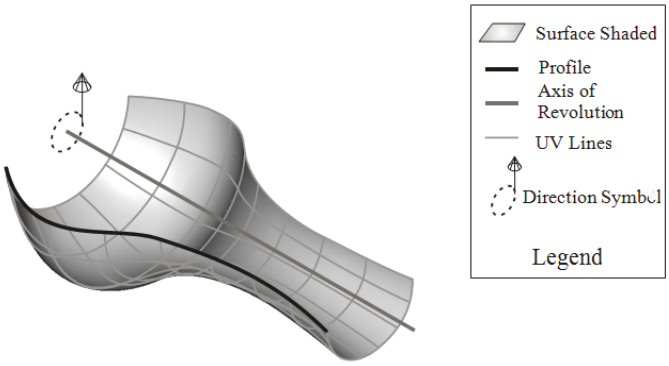
RULES AND SUGGESTIONS FOR LOFTED SURFACES

- The same tips for **Ruled Surface** drive curves apply for **Lofted Surface**.
- Cross sections should exist on the same **Cplane**. If needed, use the **Transform Project**, **Plane** function to force all entities in a cross section to the same plane.
- Chain all drive curves in the same direction or the surface will twist.
- For problems with spline drive curves, check for excess node points and consider removing excess nodes.
- If the problem persists, use **Analyze Dynamic** to check for nodes that incorrectly reverse the spline abruptly. Re-create the spline if all else fails.

REVOLVED SURFACE

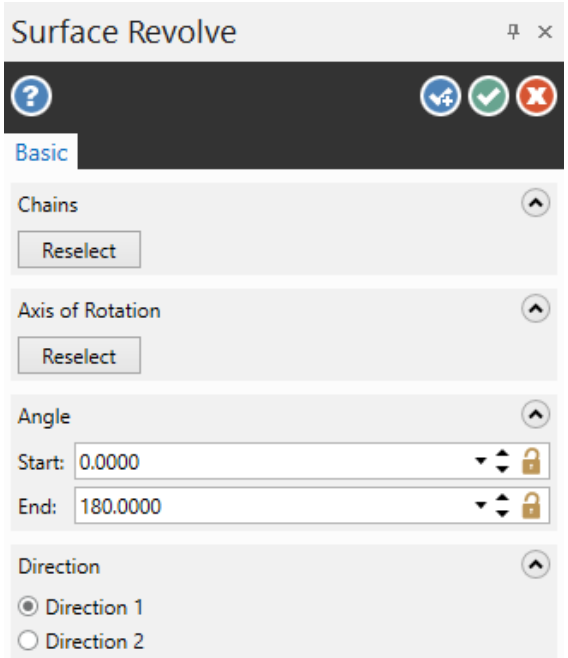
A **Revolved surface** is created by spinning a profile about a line, called the axis of revolution as shown in Figure: 4. This line must exist before the revolved surface function is selected. This example uses the file, REVOLVESURF.MCAM.

Figure: 4



Revolved Surface

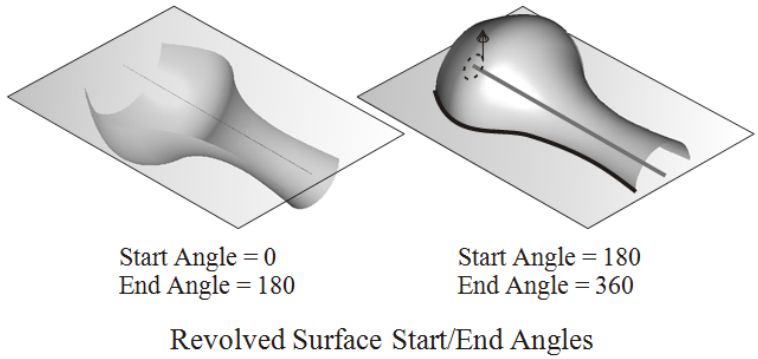
Revolved surfaces are controlled by the panel shown below.



Item	Definition
Chains Reselect	This button allows you to reselect the curves to be revolved.
Axis of Rotation Reselect	This button allows you to reselect the axis of revolution. An existing line that the profile will be spun around.
Angle Start	Degrees of rotation where the surface begins, in relation to the plane that the profile resides in.
Angle End	Degrees of rotation where the surface ends.
Direction 1 / Direction 2	Flip direction of revolution.

Angles are in reference to the construction plane (Cplane) that the profile lies in, as shown in Figure: 5.

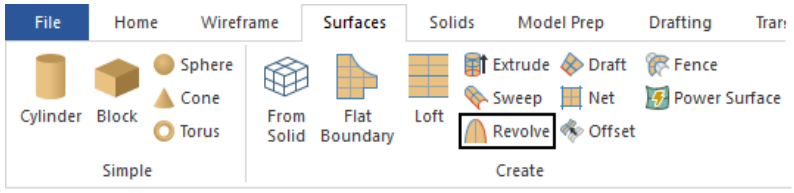
Figure: 5



Revolved Surface Start/End Angles

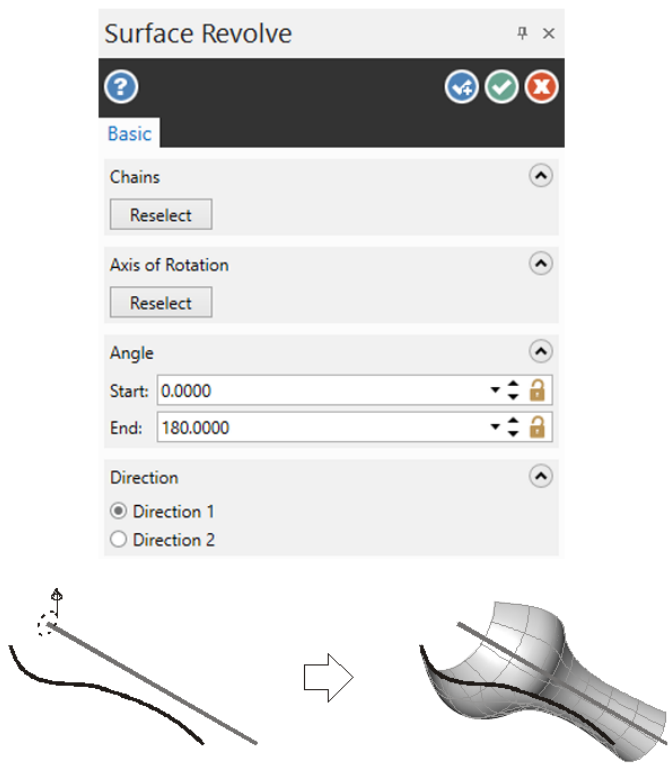
Follow the steps below to create a revolved surface. This example uses the file, REVOLVESURF.MCAM, which is included on your student CD.

- **Step 1:** Select the **Surfaces** tab and from the **Create** group, select the **Revolve** icon.



- **Step 2:** Chain the profile to revolve, and then select the axis of revolution.
- **Step 3:** Enter the **Start** and **End Angles** as shown in Figure: 6. Use **Direction 2** to toggle between the angles entered and their inverse. Select **OK and Create New Operation** or **OK** when done.

Figure: 6

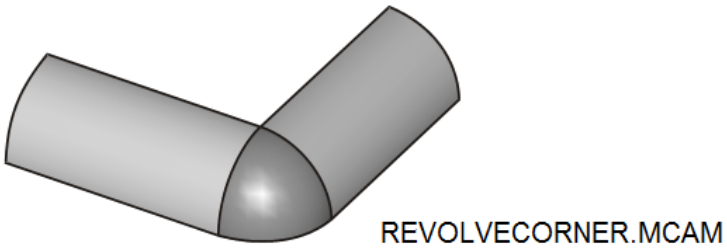


Note: Cross section cuts taken of revolved surfaces along the axis of revolution are arcs. Toolpaths created across revolved surfaces may take advantage of machine **G18/G19** arc commands, significantly reducing G-code file size.
Use a **Revolved surface** when the shape can be formed by spinning a profile around a line.

RULES AND SUGGESTIONS FOR REVOLVED SURFACES

- Multiple entities in the profile curve will result in multiple revolved surfaces.
- To create a single revolved surface, use the Create curves spline function to convert the curves to a spline before creating the surface.
- Revolved surfaces are very efficient types. Consider using a revolved surface to create rounded corners like those shown in Figure: 7 rather than using more complex surface types.

Figure: 7

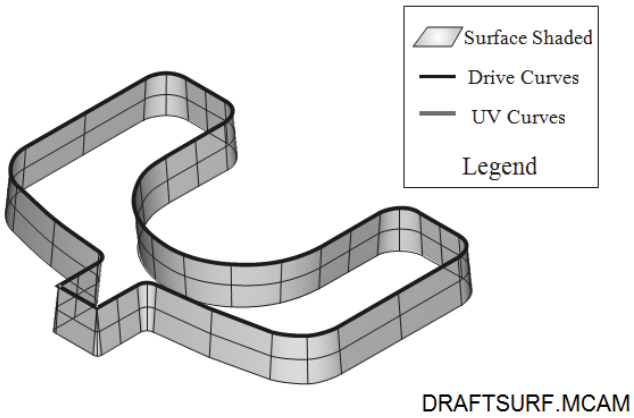


Revolved Surface on Rounded Corner

DRAFT SURFACE

A **Draft surface** is formed by sweeping lines along a contour at a constant taper angle. Draft surfaces require only one drive curve as shown in Figure: 8.

Figure: 8

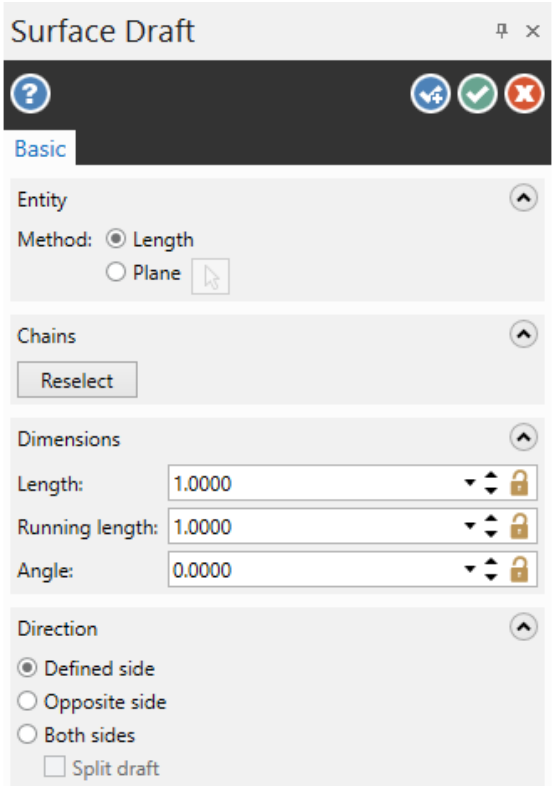


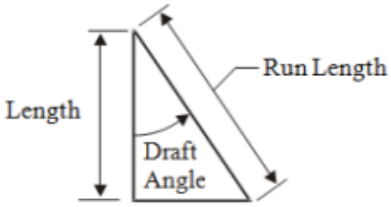
Draft Surface

After chaining the profile to draft, the Surface Draft panel is presented as shown in Figure: 9. This panel lets you control settings related to the surface including length and taper angle.

Consider using a **Draft surface** if the shape is a wall with a constant height and angle as shown in Figure: 9.

Figure: 9



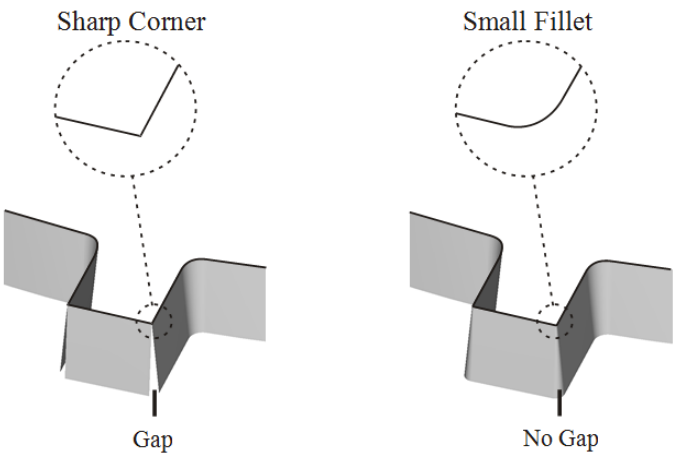


Item	Definition
Method	**Length** allows you to enter the length measured from the top of the draft surface to the bottom. It is measured normal to the plane that the drive curves lie in. **Plane** creates a draft surface trimmed to a defined plane. When the plane is selected, a plane icon appears. Click on this icon to select or define the plane.
Chains Reselect	Re-select drive curves.
Length	Allows you to enter the length value.
Running Length	The length of the resulting surface walls. Mastercam automatically calculates run length based on length and angle.
Angle	The angle of the wall from vertical.
Defined side	Automatically creates the surface on one side of the drive curves.
Opposite side	Changes the surface(s) direction on the opposite side of the drive curves.
Both sides	Generates the surface(s) in both direction from the drive curves.
Split Draft	Extend and taper the surface in both directions.

RULES AND SUGGESTIONS FOR DRAFT SURFACES

- Avoid creating draft surfaces with very complex drive curve chains. These can become unwieldy or may fail to work altogether. Instead consider modeling the draft feature with several smaller and simpler draft surfaces.
- In cases where you want or need a single surface, you can usually convert the curves to a spline using the Create spline curves function.
- ID sharp corners will create overlapping surfaces when drafting inward.
- OD sharp corners can create gaps in the walls, as shown in the illustration below. If the design allows, this may be solved by creating a very small fillet (.001 inches) on the sharp corners as shown in Figure: 10.

Figure: 10



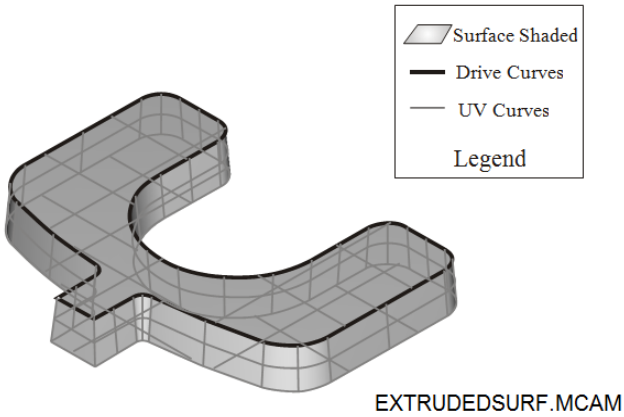
Sharp Corners vs. Filleted Corners

EXTRUDE SURFACE

Extrude surface works in a way similar to **Draft surfaces** with the following differences:

- Extrude surfaces require a closed boundary profile as shown in Figure: 11. Draft surfaces do not.
- Extrude produces a closed (watertight) volume bounded by surfaces on all sides. Draft creates only wall surfaces.
- Extrude handles external sharp corners differently and do not produce gaps.
- Extrude offers more control including scale, rotation and offset from the original profile.

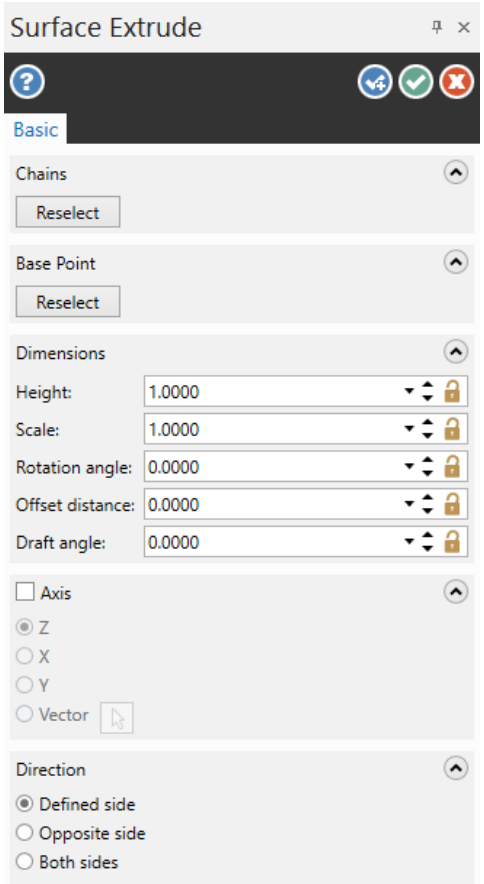
Figure: 11



Extruded Surface

Consider using an Extrude surface to create a drafted, watertight surface model.

Extrude surfaces are controlled by the following panel:

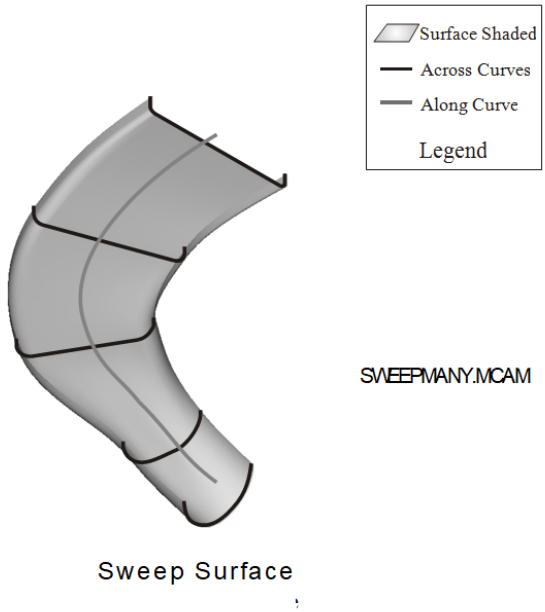


Item	Definition
Chains Reselect	Re-select drive curves.
Base Point Reselect	Allows selection of a point to position the surface.
Height	Distance from the top of the draft surface to the bottom, measured normal to the plane that the drive curves lie in.
Scale	Scales profile.
Rotation angle	Rotates profile.
Offset distance	Offsets profile.
Draft angle	The angle of the wall from vertical.
Axis	Activates the axis options. Select X, Y, Z or an axis of your choice. If not set, extrusion direction is normal to the Cplane the geometry is drawn in; not the active Cplane.
Defined side	Automatically creates the surface on one side of the drive curves.
Opposite side	Changes the surface(s) direction on the opposite side of the drive curves.
Both sides	Generates the surface(s) in both direction from the drive curves.

SWEEP SURFACE

Sweep surfaces are formed by sweeping one or more contours, called **Across contours**, along one or more other contours, called **Along contours** as shown in Figure: 12.Figure: 12 **Along** and **across contours** may be made up of lines, arcs, splines, or any combination of these.

Figure: 12



Consider using a **Sweep surface** when the shape can be formed by sweeping one or more (**Across**) contours through a trajectory of one or two other (**Along**) contours.

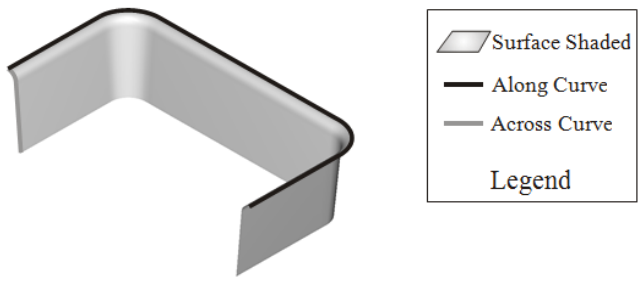
SWEEP TYPES

The following types of sweep surfaces are supported.

Many Across, One Along
Figure: 12 on the previous page is an example of this type of **Sweep surface**.

One Across, One Along
Sweep surfaces can also be created by sweeping a single across contour along one along contour as shown in Figure: 13.

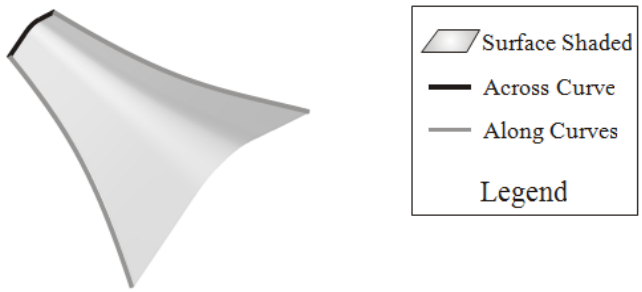
Figure: 13



Sweep: One Across, One Along

One Across, Two Along
Sweep surfaces can have a single across contour along two along contours as shown in Figure: 14.

Figure: 14

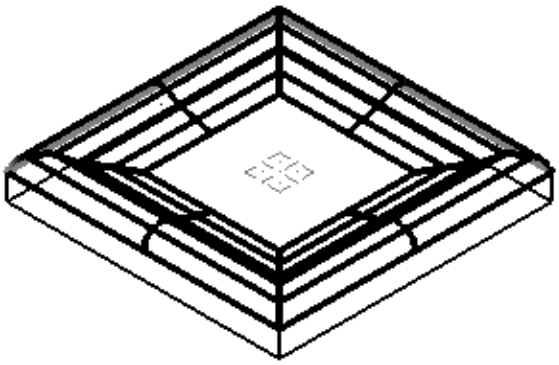


Sweep: One Across, Two Along

SWEEP SURFACE WITH SHARP CORNERS

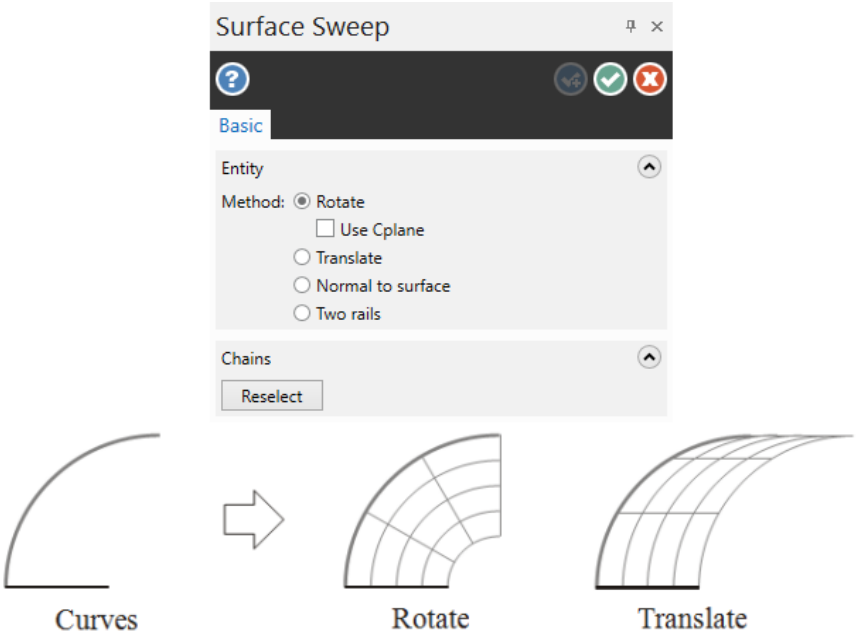
Sweep surface can now have sharp corners in the rails as shown in Figure: 15. Mastercam now builds these types of surfaces, but breaks the surfaces in multiple pieces when necessary.

Figure: 15



Sweep surfaces are controlled by the panel shown in Figure: 16.

Figure: 16



Rotate vs. Translate Across Contour

Item	Definition
Rotate	Sets the movement of the across curve relative to the along curve. In the case of Rotate the curve can rotate and twist as it sweeps down the along curve.
Use Cplane	Sets the Z axis of the current construction plane as one of the axes of the across curve's moving coordinate system.
Translate	Sets the movement of the across curve relative to the along curve. In the case of Translate the across curve sweeps down the along curve with no rotating or twisting.
Normal to Surface	Specifies that the along curve lies on or over a surface and that the across curve will maintain a consistent relationship with the surface.
Two Rails	This is the only swept surface method that allows two along curves to control the across curve.
Chains Reselect	Allows you to reselect chains.

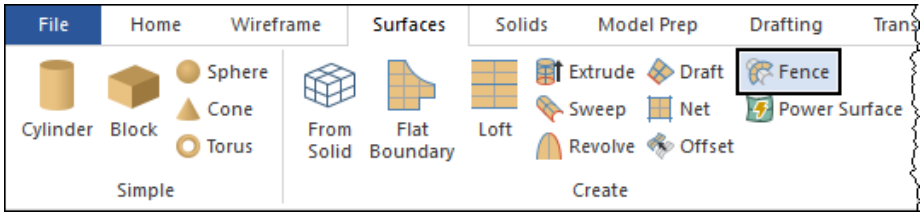
RULES AND SUGGESTIONS FOR SWEEP SURFACES

- Chain the across contour(s) first and then select OK in the chaining dialog box. Mastercam will prompt to select the along contours).
- Look for twists in the surface. Twisting may indicate that a **Sweep surface** will not be appropriate for this shape.
- After creating the surface look at the **UV** curves to ensure they form an orderly path.
- Also use shading to check the result. Twists and inflections are usually easy to spot when the surface is shaded.
- Avoid overly complex **Sweep surfaces**. Very complex along contours can result in an unwieldy surface.

FENCE SURFACE

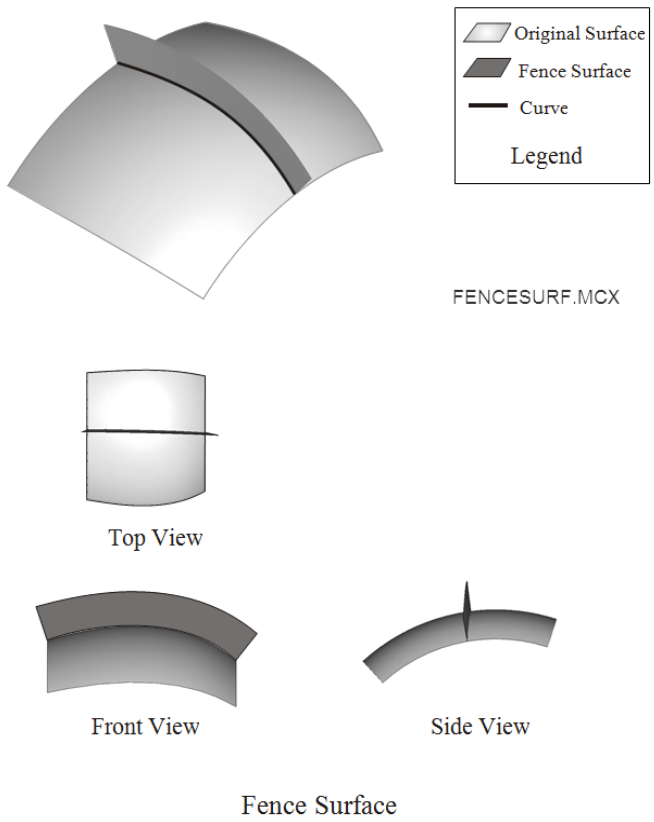
A **Fence Surface** is a ruled surface that is created from a curve lying on a surface as shown in Figure: 17. The curve does not have to lie exactly on the surface.

To create a **Fence** surface, from the **Surfaces** tab in the **Create** group, click on the drop down arrow next to Net and select **Fence** as shown.

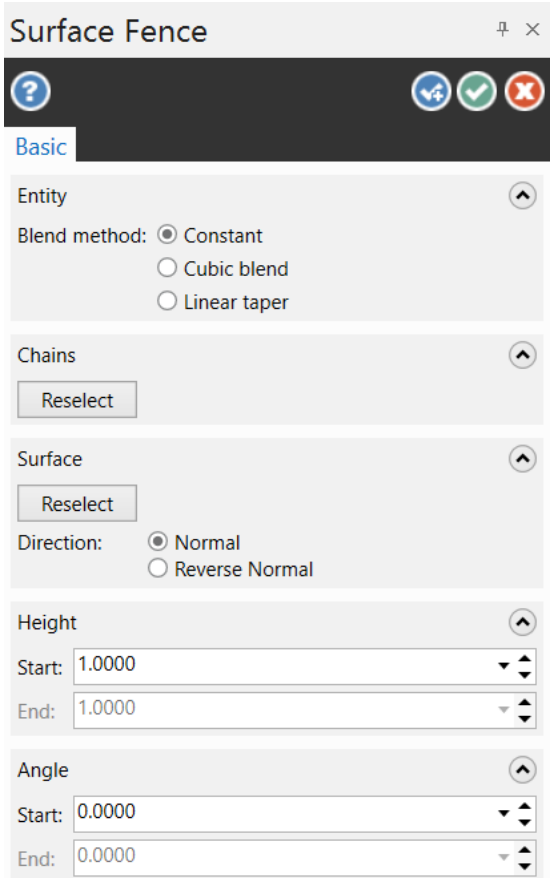


Mastercam allows control over the blend type, start and end heights and angles of the fence surface.

Figure: 17



Fence surfaces are controlled by the following panel:



Item	Definition
Blend Method	Set the blending method for how the height and angle of the fence surface varies along the chain. **Constant:** Height and angle are constant along the curve. **Cubic blend:** Height varies based on an S-shaped cubic blending function. **Linear taper:** Height varies at a constant rate from the start to the end of the surface.
Chains Reselect	Allows you to reselect chains.
Surfaces Reselect	Allows you to reselect a surface.
Direction	Flips side of original surface the fence surface will be created on.
Height	**Start Height** of fence at the start of the curve. **End Height** of fence at end of curve.
Angle	**Start Angle** from perpendicular to the original surface at the start of the fence surface. Angle is leaning left or right from a direction perpendicular to the fence path. **End Angle** from perpendicular to the original surface at the end of the fence surface.

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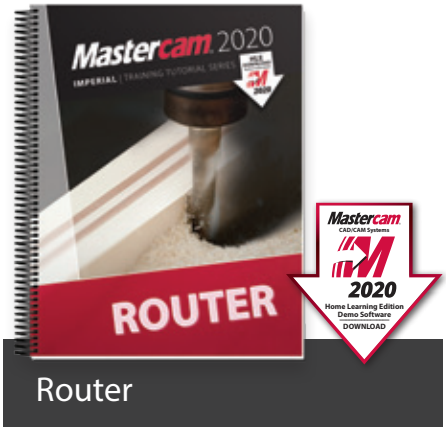

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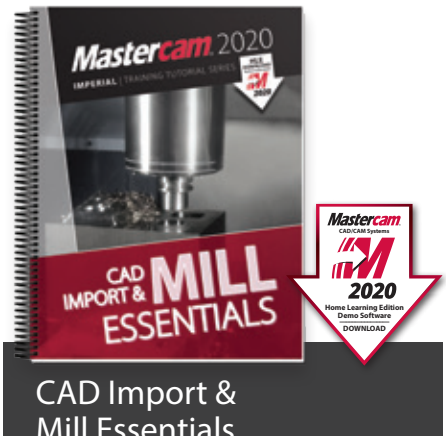

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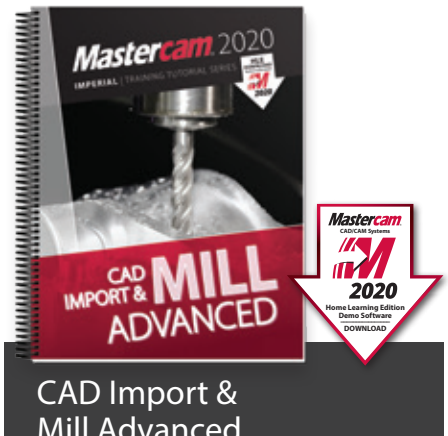

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