Choosing Toolpaths

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The movement of the tool during the milling operation is referred to as the *toolpath*. There are very real physical limits to how the toolpath should be defined; only so much material can be removed by the cutting tool with any one cut.

1. For each tool, the manner and amount of material to be removed is controlled through the speed of the tool and the path it follows.
2. A poorly-defined toolpath can cause material damage, damage to the tool, and can potentially cause bodily harm.

**Toolpath Strategy**

The most important factor in the outcome of a milled model or part is the strategy for removing material. This strategy will vary depending on the geometry of the part and the material being used. Controlled through the toolpaths programmed in Mastercam, this strategy will be composed of the number and types of toolpaths used, the order in which they are executed, and the tools chosen for each toolpath.

Some issues to consider: Do you wish to see tool marks, or would you prefer a smooth finish? So you want to mill pockets to put buildings in, or build positive forms on the landscape?

These are some things to consider early on, although by no means the only issues. Your tooling strategy will determine not only what your model looks like, but also the time it will take to cut. A more efficient set of toolpaths can dramatically improve overall finish while decreasing cutting time. Choose carefully to make the best use of your time and money spent on the materials.

What is a toolpath?

- Removing material safely
- Different materials have different requirements.

**Surface Milling from Block Material**

Rough to Finish

**2D Contour Cutting in Sheet Material**

Interior cuts then Exterior

**Toolpath Types**

The most common toolpaths used at the GSD:

- Parallel
- Contour (Surface)
- Scallop
- Shallow
- Contour (2D + 3D)
- Pocket
- Drill

A combination of these will lead to satisfying results on almost any job. Once you have gained experience with these there are further ways to customize your toolpaths in order to cut the material exactly the way you wish to, so do not be afraid to explore outside of this list.

- Flowline
- Radial

**Rough Parallel**

Typically first toolpath used in a model to removes bulk of material from all surfaces.

The rough parallel toolpath moves the tool in equally spaced parallel passes in the XY plane across the surface. Like all rough toolpaths, it cuts the surface in several Z steps. Rough toolpaths are done with large diameter tools and coarse settings in order to remove material efficiently before cutting a finish pass with finer settings.

This example shows a rough parallel pass, which is easy to set up but has limitations. Other types of roughing passes are available. (Annotat
e step over? animated gif or series of images? show drive geometry to illustrate the resulting form being influenced by step over+step down)

- **Parallel**
  The parallel toolpath moves the tool in equally spaced parallel passes in the XY plane across the surface.
  - angle
  - scallops on vertical faces
  (insert image)

- **Surface Contour**
  The surface contour toolpath works much like a topographic map, cutting along a series of paths at incremental heights (stepdowns). As a surface becomes steeper the paths get closer together; as a surface becomes more shallow, the paths are spaced farther apart. For this reason it is generally unsuitable for clearing material from a horizontal surface, but is excellent for removing material from vertical or very steep surfaces prior to other finish toolpaths.
  
  This is different from the contour (2D and 3D) toolpath.

- **Constant Scallop**
  Surface Finish Constant Scallop
  
  The constant scallop height toolpath moves the tool over the surface in a spiral motion, from the inside-out or the outside-in. The stepover is a fixed amount, but it is calculated parallel to the surface at the location being milled (rather than in the XY plane as with the parallel toolpath. It will make small pockets in some places, if necessary.

  This is an excellent toolpath for rolling terrain. It gives a very uniform, consistent result on all surfaces when used with a ball endmill. Use with one large blanket terrain surface with smaller road surfaces below.
Surface Shallow

Surface Finish Shallow

The surface shallow toolpath will cut all surfaces that are sloped less than a threshold number of degrees, which you set.

This toolpath is especially useful for urban or stepped site models that have many mostly horizontal surfaces. It cuts all selected surfaces independently of one another in spirals from the inside-out or the outside-in. The outside of the toolpath follows the edge of the surface exactly, so there is no scalloping left on the vertical faces between surface edges.

Keep in mind that some surfaces may be too tall or too far apart for the tool to cut without colliding with taller surfaces.

Pocket

The pocket toolpath removes material from within a closed curve, creating recessed areas with flat-bottoms. The pocket toolpath is useful for creating building footprints that are cut into smoothly milled terrain. Milling terrain and pockets separately will result in a cleaner looking model that takes less time to cut than trying to incorporate both feature types into one toolpath.

Pockets require closed 2D curves (all in planes parallel to the World Top CPlane) located at the bottom of the desired recessed areas.

Radial

The radial toolpath cuts radial spokes out from a centerpoint. The spokes are arrayed with equal spacing of a specified number of degrees. As a result, the stepover and scallop height increases furthest from the centerpoint. Although this is not a widely used toolpath, it can lead to some very interesting textures. Both a set of surfaces and a point to specify the centerpoint are required.
Flowline
The flowline toolpath follows the shape and direction of the surface geometry. Basically, it moves the tool along isocurves. It can be used to very nice effect on curvy, linear surfaces, such as swept surfaces.

It will not work in all instances and requires an orderly row or grid of surfaces where surface isocurves are continuous.

Contour (2D or 3D)
The contour toolpath (not surface contour milling) can be used to direct the tool cut along a curve. The curve can be planar or 3D.

By default, the cutter will cut fully to the left or the right of the curve. It is possible to turn the compensation to “off” to make tool cluster cut down cutter of line)

The contour toolpath can be used as a clean-up pass to remove scalloping from a vertical face left by a previous surface milling operation as a final cutout or to trace roads/paths shallows into a surface.

The contour toolpath can also be used to turn curve geometry directly into toolpaths that indirectly define a surface. This allows you to have total control over tool movement, which frees you to create texture for your final milled surface, without being restricted or limited by the toolpath options built into Mastercam.
Drill

The router can be used to drill holes in precise locations. Although it is possible to use endmills in a drilling operation, it is preferable to use drill bits. The AXYZ router can only use mill drills drill bits that are the same size as the toolholders. The knee mill and the Onsrud can be fitted with a chuck that will allow it to take a variety of drill sizes.

Points are used to define drill toolpaths. Drilling can be done to a predetermined depth, or points can be projected onto a 3D surface and the drill will drill to the depth of the point.

(Import Illustrator with holes at varying depth defined clearly by points)