A Hanging Lathe…

The MachStdMill project: Turning parts with a Mill
By Calypso Ventures, Inc.

Have you seen the pictures of tomatoes growing upside down? An occasional change in perspective can do one good; it might even save you the price of a CNC lathe…

If you have a CNC mill, but not a CNC lathe, and you've wanted to make CNC turned parts for a project, you may be interested in the ability to do turning on your CNC mill; an ability I'll refer to as "Mill-Turn".

Turning a Mill into a lathe:
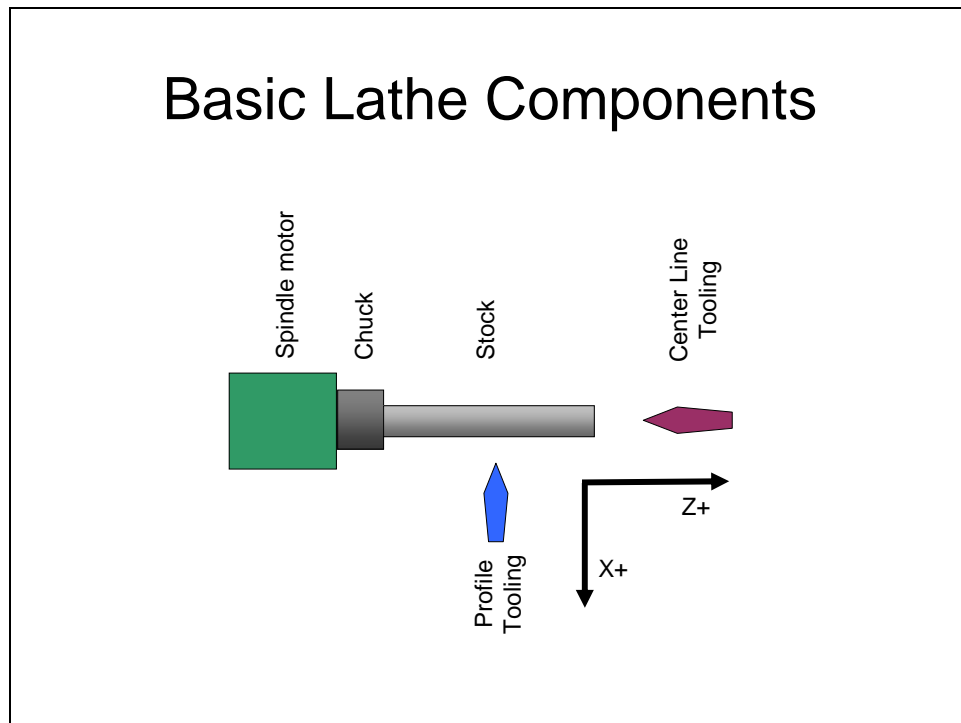Let's consider the basic parts of a lathe as shown in Figure 1:

Figure 1: Basic Lathe Components

The diagram is typical of a horizontal manual lathe with a "front tool post" (where the tool post is between the operator and the spindle center line). Horizontal CNC lathes, often flip the profile tooling to the opposite side of the center line and are referred to as having a "rear tool post" configuration.

A CNC lathe controls motion for two axes: X & Z. CNC Lathes also have a third (Y axis) adjustment which is used to set profile tooling height wrt to the stock center line. Y is generally assumed to be a static adjustment done per tool and it's taken care of when

setting up a profile tool. This is what the height adjustment knobs on quick change tool posts are setting. Because of the static nature of the Y setting, the Y axis for a CNC lathe is generally not under computer control.

In addition to horizontal lathes, vertical lathes are common in industry. They essentially rotate the picture so that the spindle is at the bottom (as it's the big heavy part).

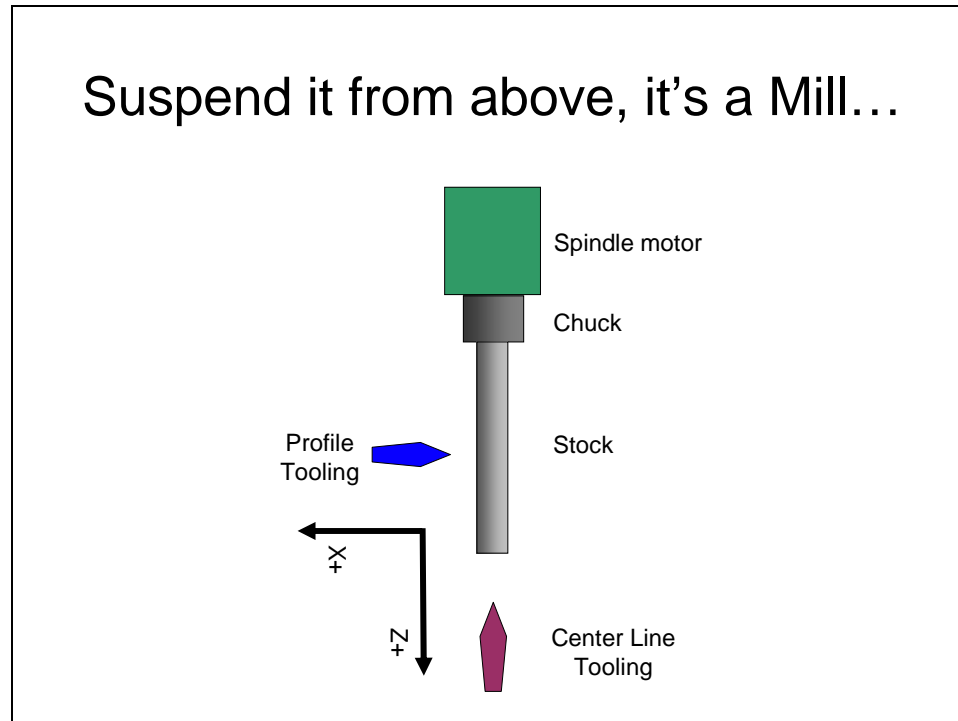What do we get if we wave a magic wand and hang the lathe spindle motor from the ceiling…?

Figure 2: A Hanging Lathe

Figure 2 looks a lot like the typical vertical mill. This observation got me to thinking about enhancing my CNC mill's control software to enable the use of the mill to do turning operations. Like a lot of small personal shops, I didn't have a CNC lathe and using the mill for turning seemed an attractive way to augment my shop capabilities.

The primary physical limitation would be an inability to do turning operations that require a tail stock, while the software challenge would be to have the computer handle the Y axis (which would not be fixed on the mill). The project would also need to give some thought to various ways of holding lathe tooling on the mill.

Lathe tool holding on a Mill:
Figure 3 is a picture of a simple Mill-Turn tooling set up where a lathe tool is simply held in the mill vise:

Figure 3: Lathe tool held in mill vise

This works OK, but is not conducive to handling multiple tools. It also suffers from a need to re-measure tool offsets each time a tool is mounted in the vise.

As I had a manual lathe, it seemed that the ability to use it's tooling on the mill would be nice. This lead me to create a simple tooling fixture for use on the mill:
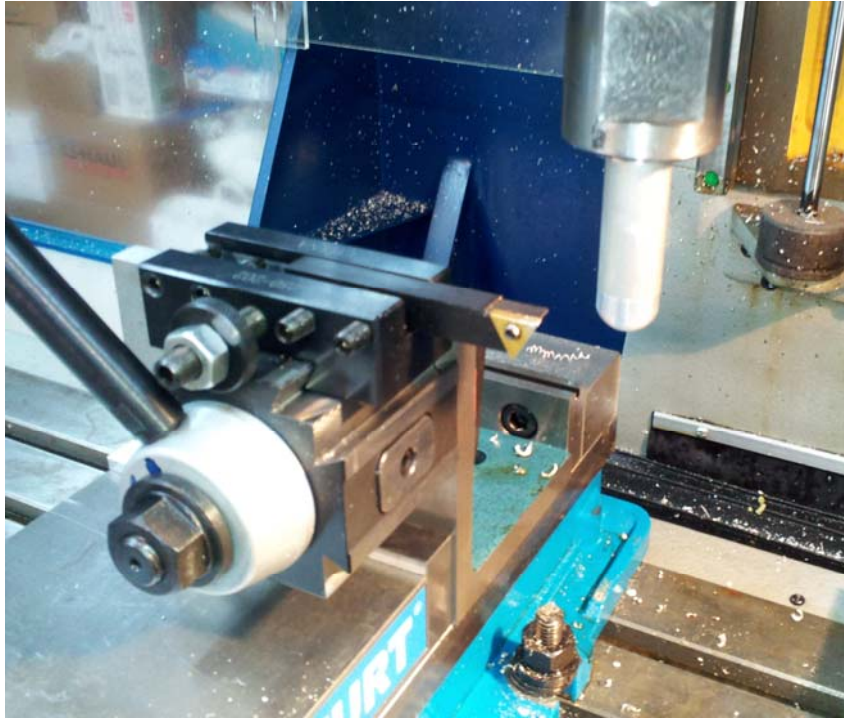
Figure 4: Mill-Turn Quick Change Tool Post Fixture

The simple fixture in Figure 4 (it's just a right angle held in the vise) allows for repeatable position mounting of both profile tooling and center line (e.g. drilling) tooling. In Figure 5 we have a picture of a center cutting tool mounted on the fixture:
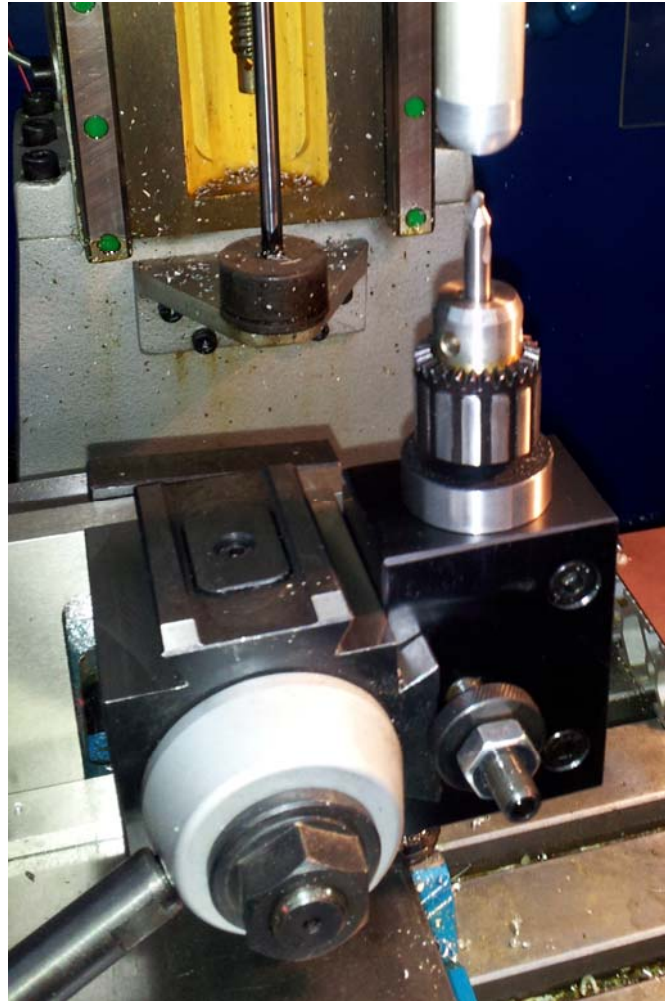
Figure 5: Mill-Turn Quick Change Center Tool

With the physical mounting of tools handled by the fixture, I shifted attention to the software aspects of positioning the tools relative to the spindle center line.

To do turning operations on a mill, it becomes necessary to determine how to handle the 3rd axis (Y), which is fixed on a CNC lathe. The design goal was to find a way to do this so that existing 2 axis lathe G-Code could be run on the mill - <u>without requiring modifications to the lathe G-code</u>. That desire led to a design where the control software handles all the Y axis specific aspects of the tool's set up with a combination of tool change logic and tool table offset values. When executing Late G-Code, this is handled transparently as part of the tool change actions, thereby keeping the Y axis handling independent from the lathe G-Code.

As the author of the MachStdMill (MSM) software package, I thought this Mill-Turn ability would make a nice feature enhancement for the MSM software. I'd received many requests for a lathe package to compliment the MachStdMill product, but there are

fewer CNC lathe users than CNC mill users in the hobby segment of the CNC tool market. This had limited our interest in doing a CNC lathe (only) specific project. The project idea became to approach this from the Mill-Turn perspective (the 3 axis situation). With a little forethought the lathe support requests could also be satisfied (as it's a 2 axis sub set of the mill-turn case).

The project resulted in the addition of both Turn and Mill-Turn support to the existing software feature set. CNC Mill owners are reporting that they can now easily make many turned parts with their mills. Of course, there are physical limitations to what can be done on the mill, as you can't use a tail stock, and you have to pay attention to overhang ratios etc. Within these limitations, a lot of lathe parts are possible using a CNC mill. I also liked the fact that using existing equipment was a lot less expensive than buying a CNC lathe.

Mill-Turn Software Support:
Let's take a closer look at how the Mill-Turn software make these parts possible.

When the Mill-Turn software starts up, the initial screen page is the lathe equivalent of the MSM Mill Load page. This follows the Load-Offsets-Tooling-Run workflow that has proven popular with the MSM software[1].

In this article, I'll show only the Mill-Turn screens (as the two axis Turn only screens are very similar, they simply omit the Y axis specific controls).

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[1] See the Digital Machinist Volume 6, No. 2, Summer 2011 issue for a description of the MachStdMill software work flow.
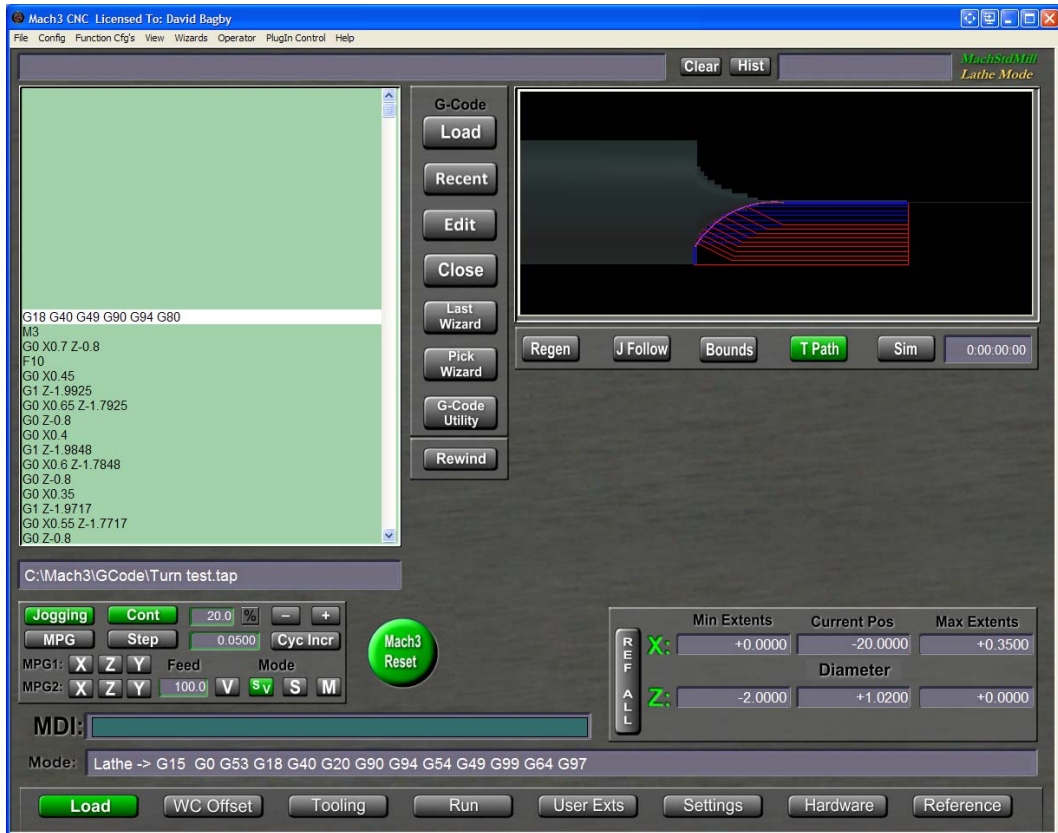
Figure 6: Mill-Turn Load screen

This Load page is used to load/create lathe G-Code, find the physical extents of the program and simulate the part to estimate the part running time.

The WC Offset screen is where the operator first see some Mill-Turn controls specific to the Y axis.
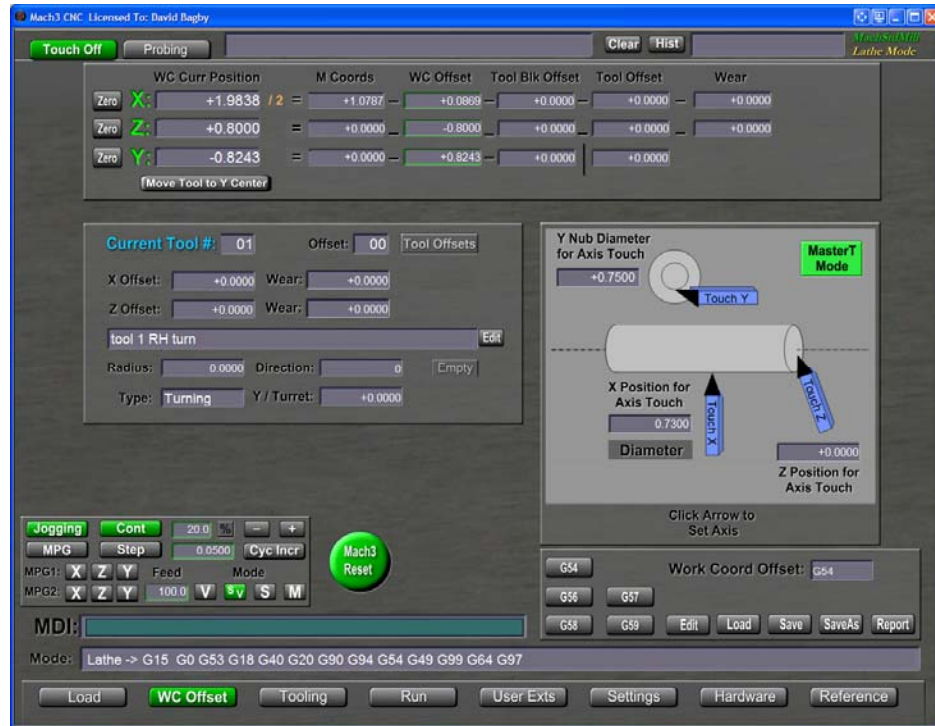
Figure 7: Mill-Turn WC Offsets Screen

Figure 7 shows the "touch off" page for setting tool offsets.

To set the X offset, a skim cut is made on the stock, the resulting diameter is measured and entered into the "X Position for Axis Touch" DRO and the "Touch X" tool graphic is clicked. This causes the system to calculate and save the X tool offset value to the tool table.

For the Z offset, the operator typically makes a facing cut, enters 0 in the "Z position for Axis Touch" DRO and clicks the "touch Z" tool graphic.

To handle the Y axis aspects of tooling for Mill-Turn, the concept of a Y axis tool offset was created. When setting up a turning tool, the operator sets the usual X and Z tool offsets (as for a normal XZ only CNC lathe) and also sets up a Y axis offset.

The additional Y axis offset is handled in a similar manner to X& Z touch off. An off center facing cut is made, the diameter of the resulting "nub" is measured, entered into the "Y Nub Diameter for Axis Touch" DRO and the "Touch Y" tool graphic is clicked. The software calculates the Y offset and stores it in the tool table[2].

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[2] Astute readers may be wondering about this since a lathe tool table only has entries for X& Z. The MSM software also extends the tool table to handle Y offsets for Mill-Turn use.

From this point on, the software can now calculate how to position the tool on the center line of the stock along Y as part of the tool change logic. The software keeps track of the 3rd (Y) offset and applies it when a Mill-Turn tool is mounted.

Center Cutting Tooling
The addition of the Y offset handles one major part of the Mill-Turn design. However, more support was needed to create a general solution to handle center cutting tooling. A new tool attribute was created that tells the software if a lathe tool is center cutting tool or not. The use of this attribute enables the software to support a generalized tooling plate.

Figure 8 has a picture of another tooling fixture created by an MSM Mill-Turn user:

Figure 8: Mill-Turn fixture with multiple Center tools

This user wanted the convenience of having multiple center tools ready to use.

Wait a second, each center tool is at a different XY location on the mill… how are they going to get lined up with the spindle center line? The software also handles this for the operator as part of the tool change sequence.

The combination of the X and Y offsets uniquely identifies the position of each center tool. When a tool is marked as a "center tool" in the tool table, the MSM software also positions the tool on the spindle center line as part of the tool change sequence.

The software provides support for an arbitrary tooling plate, with any number of center and profile tools.

Offset Probing:

The probing abilities already built into MSM were further enhanced to make setting up the locations of all these tools easy. This required providing 3 axis probing support while Mach is running in 2 axis Turn mode[3].

The Mill-Turn software has one click support for finding the center XY position of a center tool. An example is shown in Figure 9 of one of the WC Offset probing pages for Mill-Turn:

Figure 9: Mill-Turn Tool Offset Probing

Alpha testing the software showed it would be nice if tool offsets did not have to be re-measured whenever a fixture plate was mounted to the mill. To accomplish this, all tool offsets are measured relative to a reference point on the fixture and the G52 offset facility of the control is used to locate the fixture reference point relative to the mill's machine coordinate origin.

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[3] After this was working, I was told by ArtSoft that they were not sure this was possible; sometimes ignorance is bliss…
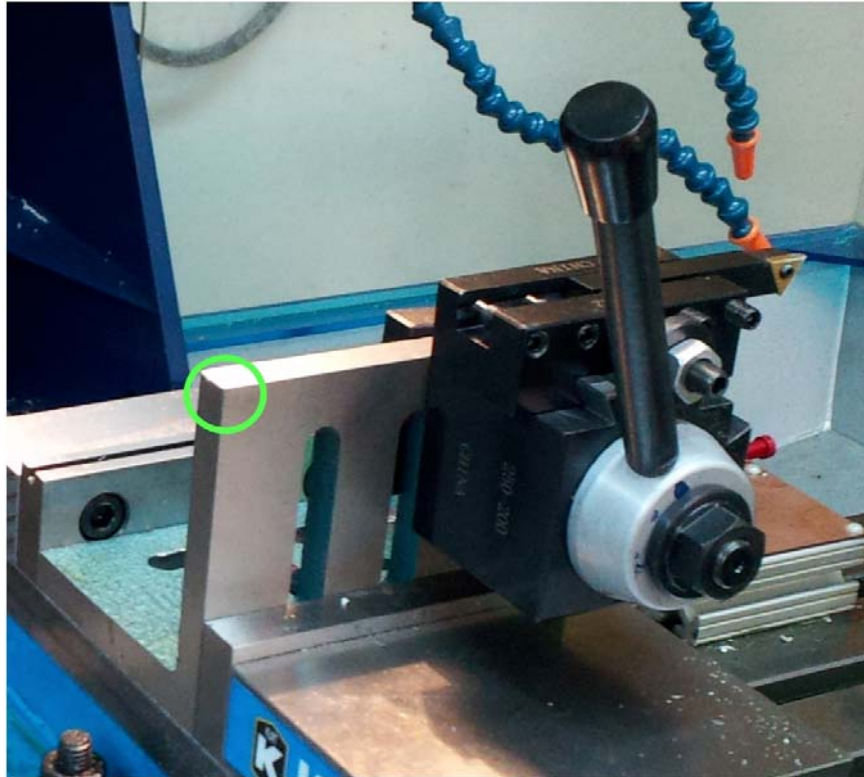
Figure 10: Tooling Fixture Origin

The complexity of this use of multiple offsets is hidden under the hood of the software to make the operators life easy. The operator simply sets up the tool offsets once for each tool, and (as long as the tools are not moved relative to the tool holders) those offsets never need to be re-set.

When the fixture is mounted on the mill (assuming you have a probe on the mill, which most MachStdMill users already have), a one click corner find operation will locate the reference corner of the fixture. Follow that with a click on the "set TB Zero" (Set Tool Block Zero) button and the software will set the location of the fixture (see next Figure 11).
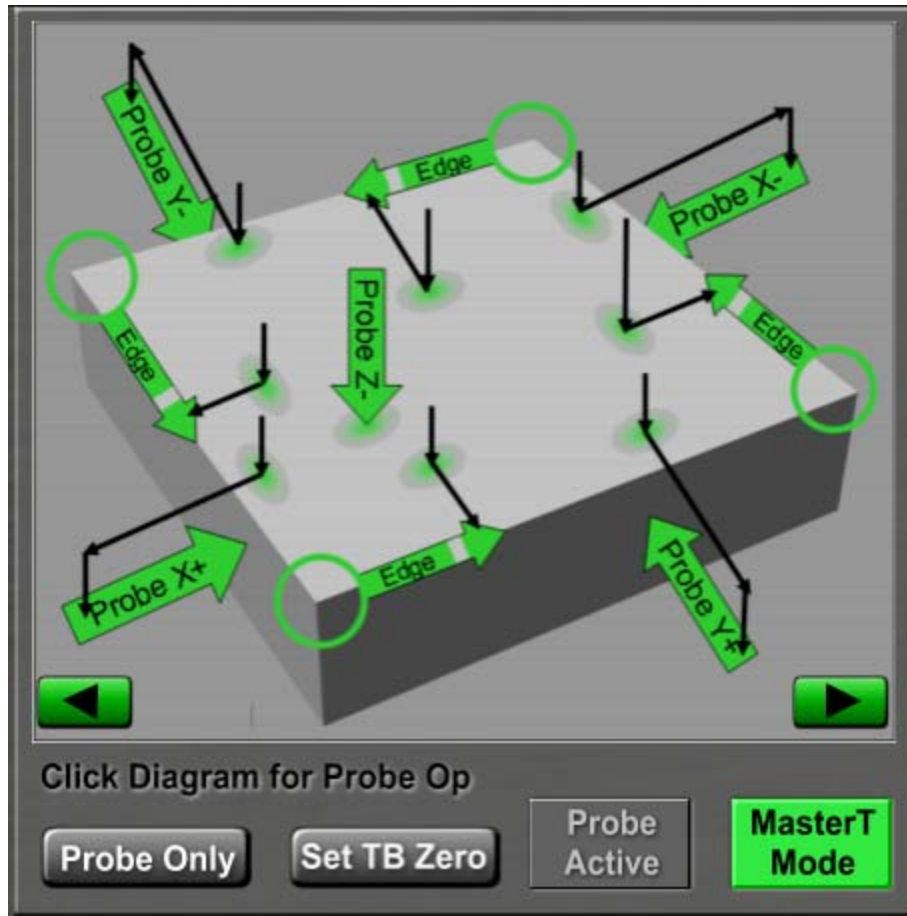
Figure 11: Mill-Turn edge finding and Set TB Zero

<u>Tooling changes:</u>

With the offsets in the tool table, and the tooling fixture located, the tool change actions can take care of all the things necessary to handle the Y axis for Mill-turn.

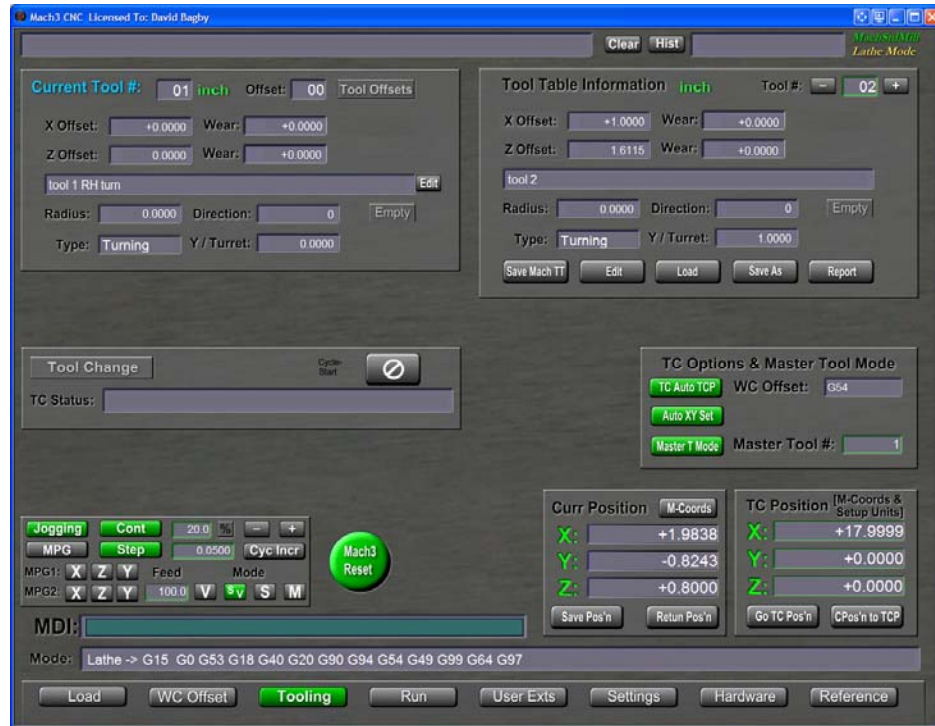Figure 12 shows the tooling page for Mill-Turn:

Figure 12: Mill-Turn Tooling page

This page is very similar in look and feel to the MSM mill tooling page. From a Mill-Turn operation perspective, the important button is located in the TC Options panel: the "Auto XY Set" button. When this button is on, a Mill-Turn lathe mode tool change will cause the software to automatically position the tool appropriately relative to the mill spindle's center line – in both X and Y. While all tools will be positioned in Y so that they are correct wrt to the center line, center tools will also be positioned in X (so that they are also on center along the X axis) if the Center Tool attribute is set.

Running lathe G-code on the mill:
The Mill-Turn Run page is shown in Figure 13.

Figure 13: Mill-Turn Run Page

The only hint that this is a Mill-Turn setup is the presence of the Y DRO panel on the page. All run time handling of the Y axis is handled by the MSM tool change software. The underlying control software (Mach) does not know anything about Mill-Turn operations, it simply thinks it is running a regular 2 axis XZ lathe.

This is how the original design goal for a set of XZ lathe screens was achieved. The straight lathe run screen is exactly the same, only the Y DRO panel is not present for XZ lathe operation.

This has turned out to be a nice addition to the CNC mill's abilities. Figure 14 is a picture of a chess piece that was made using the Mill-Turn software. This part was made with an existing lathe G-Code program provided by a CNC machine vendor, thus showing that Mill-Turn can run unmodified Lathe G-Code.

Figure 14: Chess pieces made with Mill-Turn

If you have a spindle index speed sensor connected and configured, you can also use Mill-Turn to make threaded parts with the mill.

To supplement the illustrations in this magazine article, videos of Mill-Turn in action are available at the Calypso Ventures, Inc web site on the "MachStdMill; Turning Videos" page of www.CalypsoVentures.com

The Lathe and Mill-Turn support was included in the MachStdMill 2.0 release. The MSM 2 axis turn screen set is available in the MachStdMill Personal Edition which is available *without charge for personal non-commercial use*. The Mill-Turn support is available in the MachStdMill Professional Edition.

By tilting your head and seeing the CNC lathe hiding in your mill, you can easily do many turning operations without having a CNC lathe.

Questions for the author may be directed to MSM@CalypsoVentures.com