Using a CNC Controlled Vertical Mill as a Lathe, version 1.0

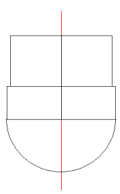
By R. G. Sparber

Copyleft protects this document.[1]

Here is how I use my RF-30 mill/drill as a CNC lathe.

See https://www.youtube.com/watch?v=ZUhv6GbeBbM for my video.

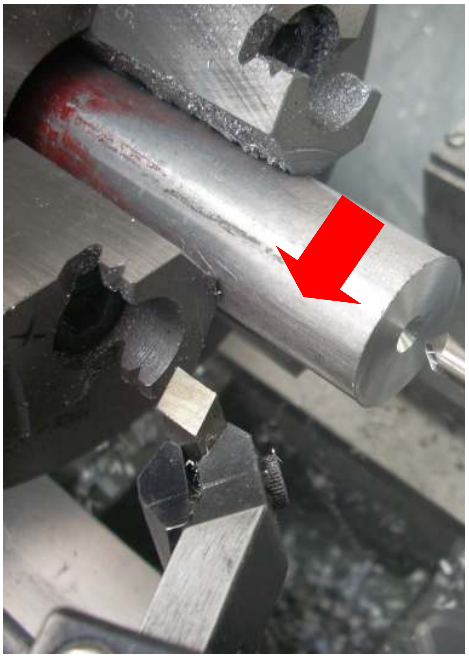
This article presents both the hardware and G-code needed to machine this part. It is 0.250 inch in diameter and 0.293 inches long. I'll need 102 of them before I am done.



If you look on YouTube, you will see[2] many fine examples of people mounting round stock in their mill's spindle and securing lathe cutters on the table. Some even secure mill cutters to the table for even more flexibility. In this way, the XY movement of the table acts as both a cutter feed and tool changer.

[1] You are free to distribute this article but not to change it.
[2] I used the search terms "cnc mill lathe turning". I found https://www.youtube.com/watch?v=IrlY8qEmO3I particularly impressive.

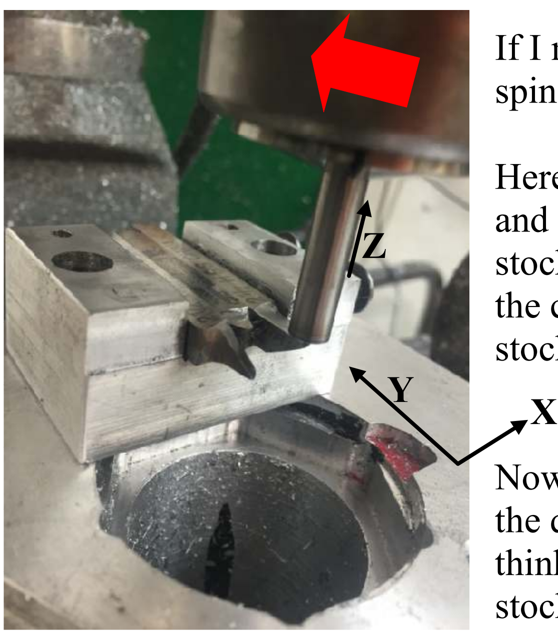
Basic Concept



I turn metal on my lathe. The stock spins counterclockwise as viewed from the tailstock. When I want to cut starting from the right and moving left, I use a left hand cutter as shown here.

When I have installed a right hand cutter, I start cutting from the left and move right.

Keep in mind that movement of the cutter is with respect to the stock. This is how the G-code is defined.



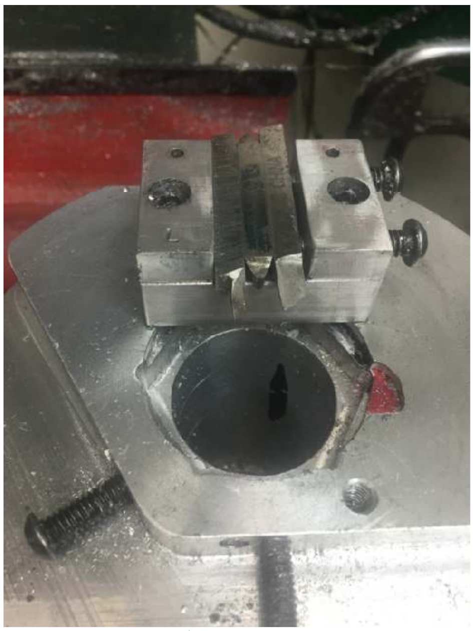
If I mount stock in the spindle of my mill, I can spin it counterclockwise as viewed from the table.

Here you see a right hand cutter touching the stock and a left hand cutter next to it. By moving the stock relative to the table in a positive Y direction, the cutter feeds in just like a lathe. Moving the stock in a negative X direction lets me move from my right hand cutter to the left hand cutter.

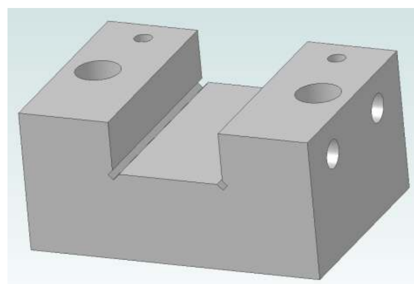
Now, the stock is actually moving up and down as the quill is retracted and extended. Yet you must think of the movement of the cutter relative to the stock. So a negative movement of the quill causes the part to move closer to the table. However, the right way to think about it is that this negative movement causes the cutter to move in a positive direction relative to the stock. Take a moment to wrap your head around this idea because it is key.

Hardware

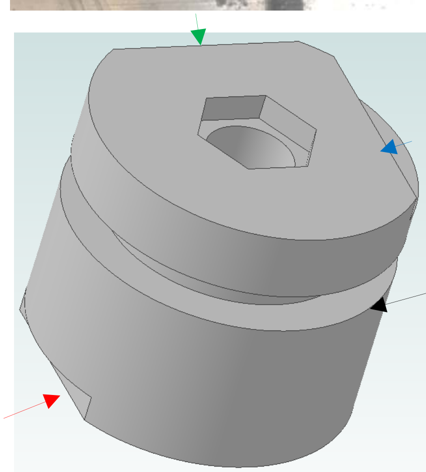
Due to other machining steps, I was forced to have the spindle rather high above the table. I already had a massive aluminum cylinder used to hold other parts during various CNC operation. I call this cylinder my hex fixture. It was then a matter of adding another attachment on top of it.



I used a 1" x 1½" X 2.1" block of 6061 aluminum to make my cutter block. More on how I machined it later.



It is secured to the hex fixture using two SHCS ¼ -20 and two dowel pins. The pins provide accurate position relative to the base and the screws keep the block from shifting.



The hex fixture has three flats machined into it used for reference. In its base is a flat (red arrow) that is set parallel to the Y axis as part of its installation.

Two hold down clamps fit into this groove and insure no movement.

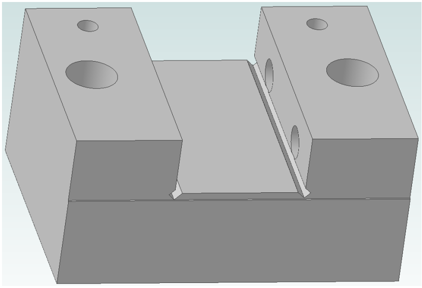
At the top is a flat along the back side that is then parallel to the X axis (green arrow) and a flat on the right (blue arrow) that is parallel to the Y axis. I use these top flats to locate the center of the hex fixture. This center point is then used to locate both parts held in the fixture and to set the Center Of Rotation (COR) of the spindle at the point of the two cutters.

In this way, I first align and secure the hex fixture, install the cutter block, find (0,0), and are ready to run the G-code.

In this side view of the cutter block, you can see a left hand cutter in the background and a right hand cutter in the foreground. The left hand cutter forms the hemisphere and the right hand cutter does the reduced diameter section and parts off.

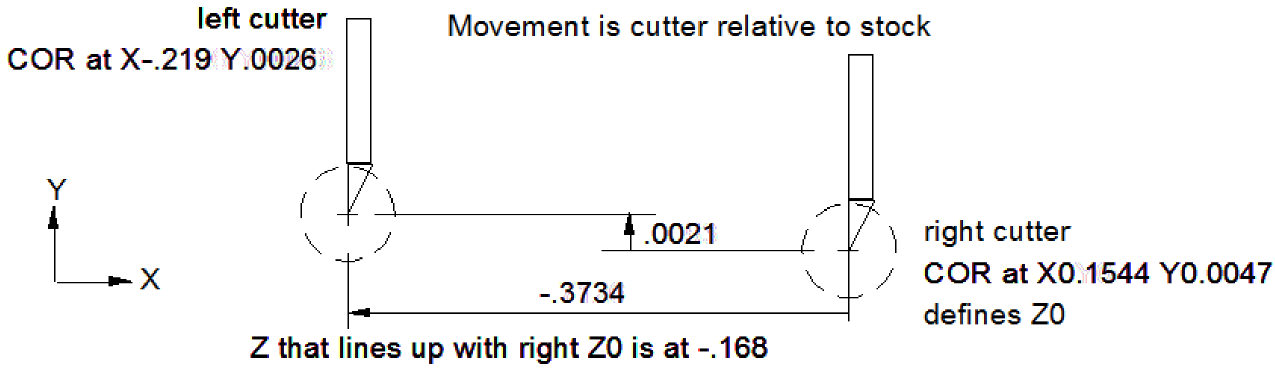
The cutter block was machined in place to give me the best possible accuracy. The left screw hole were drilled and counterbored. Then a SHCS was installed and lightly tightened. After adjusting the block so it looked reasonably parallel to my X axis reference on the back of the hex fixture, I fully tightened the screw. Then I drilled a tap hole on the right side of the block. This hole went through the block and about ½ inch into the hex fixture. The block was removed and both clearance and counterbore drilled. The hole in the hex fixture was tapped. After cleaning all surfaces, the block was again installed and the two screws fully tightened. Then the two 1/8 inch holes were drilled near the back[3]. These holes pass through the block and about ¼ inch into the hex fixture. After removing all swarf from these holes, pins were dropped in place.

[3] For more accuracy, I would have drilled slightly undersized and reamed to final.



Then I CNC cut the recess that would take 3 cutter blanks. The recess is 0.8 inches wide and 3/8 inches deep. A light cut was made across the front face of the block to define my front reference surface. This face is aligned with my X axis and will be used during set up of the cutters. After removing the block, the inside corners of the recess were relieved with saw cuts. The two locking screw holes on the right were drilled and tapped. These screws apply pressure to the flank of the right most cutter. That force is transmitted through the remaining cutters and into the wall on the left side.

During cutter installation, I use that front reference surface to set the ends of the cutter 0.500 inches out. This insures that both cutters are located at the same Y position. Well, that was the plan after I realized I needed those alignment pins. In practice the two cutters differ along the Y axis by 2.1 thou. This is not a problem because the G-code easily compensates.



Calibration was time consuming but is only needed after disturbing the cutters in the cutter block.

First the cutter block was installed on the hex fixture. Then I used my two reference surfaces to set (0,0) which is at the center of the hex fixture.

Next I mounted a short length of ¼ inch drill rod in the spindle. By eye I aligned the end of the right cutter to the COR and touched the front flank of the cutter[4] to the outside of the drill rod. This placed me 0.125 inches along the X axis away from having the COR aligned with the point of the cutter. The X DRO value +0.125 inches was recorded. Then the rod was moved so the end of the right cutter was aligned with the COR along the X axis and the back side of the rod just touched the tip of the cutter. This placed the COR 0.125 inches along the Y axis from the tip of the cutter. The Y DRO value plus 0.125 inches was recorded.

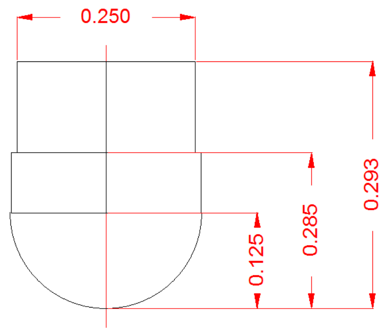
This process was repeated for the left cutter.

The Z = 0 point was defined by placing the COR at the right cutter and lowering the stock until it faced the end. Then Z was set to zero. I then moved the COR to the left cutter and fed in until I had parted off a tiny puck. The thickness of this puck told me the difference in Z between cutters. I measured 0.168 inches with my mic.

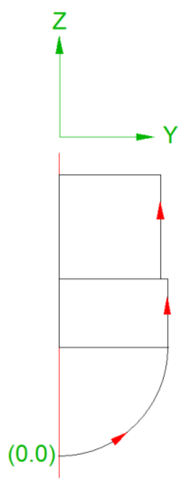
You will see all of these numbers again when I present the G-code.

[4] I detect touchdown by measuring the change in milliohms between cutter and spindle. I see above 500 milliohms before touchdown and below 100 milliohms after.

Software



This is the part I wanted to make.

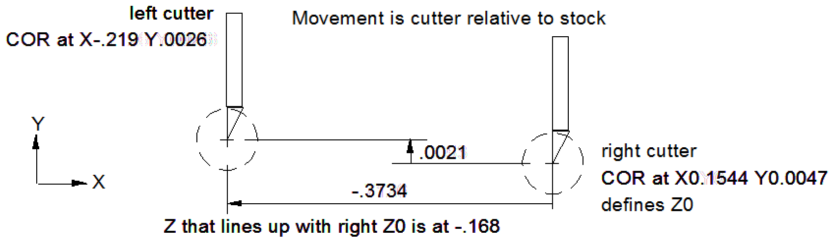


From a software standpoint, I am making this. That red vertical line is my COR which is aligned with the Z axis. I am sighting along the X axis in a negative direction so see the Y axis pointing to the right. It is pointing towards the column of the mill.

The left hand cutter relative to the part starts out at the bottom. It moves in a counterclockwise arc for 90°. Then there is a movement along the Z axis. My change to a right hand cutter means a change in X,Y, and Z. Then I feed in slightly and turn the smaller diameter section at the top of the part. Feeding the cutter into the COR parts it off.

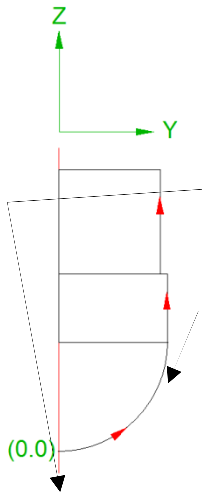
G20 G90 (inches; absolute distance mode)
G91.1 G64 G40 (incr. IJ mode[5]; constant velocity; cutter radius comp. off)
G19 (operating in the YZ plane)
(origin is the center of the hex fixture)

[5] See http://rick.sparber.org/ARC.pdf for details.



#1 = 0.1544 #2 = 0.0047(for right cutter, COR at tip is at X=0.1544 Y=0.0047)
#3 = -0.219 #4 = 0.0026 (for left cutter, COR at tip is at X=-0.219 Y=0.0026)

Here is where I define my cutters relative to the hex fixture's origin using local variables #1 - right cutter's X location, #2 - right cutter's Y location, #3- left cutter's X location, and #4 - left cutter's Y location.



G0 X#1 Y#2 (here is my arc starting point)
M0 (feed hold to set Z0.000)

The part's origin is actually at X= #1 = 0.1544 inches, Y= #2 = 0.0047 inches relative to the hex fixture's origin.

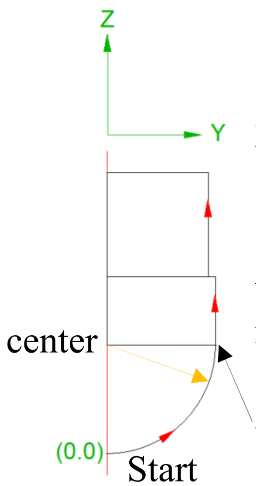
#6 =[#2 -0.125] (Y end point of the arc)
The end of the arc is -0.125 inches from the start along the Y axis. Local variable #2 defines the start of the arc on the Y axis. #6 defines the end of the arc on the Y axis.

G3 F0.2 Y#6 Z-0.125 J0.000 K-0.125 (CCW - cut round end)

I was confused about the direction of this arc until I saw that we are dealing with the motion of the cutter relative to the part. The cutter moves ***counter***clockwise. Yes, the part is actually moving along the Z axis in a negative direction and is also moving along the Y axis in a negative direction. Those motions are necessary because I wanted to move from the bottom of the part to the OD to form a hemisphere.

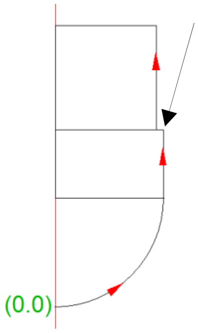
G3 F0.2 Y#6 Z-0.125 J0.000 K-0.125 (CCW - cut round end)

Let me take this block of G-code apart:
G3 (counterclockwise arc)
F0.2 (feed at 0.2 inches per second; this reduces the cutting force to an acceptable level on that ¼ inch stock which may be sticking out as much as an inch)



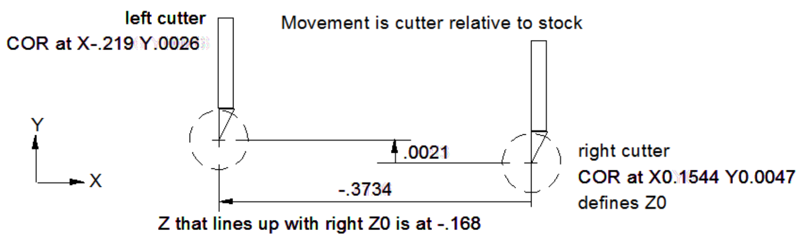
Y#6 Z-0.125 (the end point is at Y = -0.125 from the Y starting point of #2 which equals #6; the spindle fed down by 0.125 inches)

J0.000 K-0.125 (the center of the arc is offset from the start along the Y axis by zero; along the Z axis it is offset from the start by -0.125 inches. Why *negative* 0.125? Because the part moves in a negative Z direction relative to the cutter to reach the center. The G-code understands that motion is spindle relative to table. That negative Z motion permits the cutter relative to the part to move in a positive Z direction along the Z axis.
Arc ends at Z = -0.125)



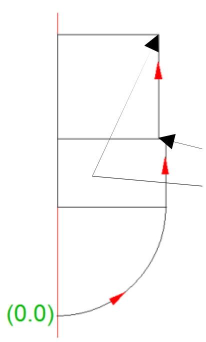
G1 F1.0 Z-0.180 (end of straight section after round end; again it looks like the cutter is moving in a positive Z direction but since it is the stock that is moving, we specify a negative Z direction.)

G0 Y-0.200 (move first cutter away from part; this is done by moving the part away from the cutter. The COR moves in a negative Y direction to back away from the cutter.)



G0 X#3 (move stock to second cutter along the X axis and put point on center line of part: X=#3= -0.219)

#5 = [#4 -0.125-.005] (calculate 0.005 above surface along the Y axis: 0.0026 - 0.125 -.005 = -0.1274)
G0 Y#5 (quickly move left cutter's point to 0.005 above surface)



G0 Z-.328 (start of small diameter: -0.168-0.160 = -0.328)
#5 = [#4 -0.125 +0.0075] (calculate cut of smaller diameter: 0.0026 -0.125 +0.0075 = -0.1149)
G1 F1 Y#5 (cutter fed in to smaller radius; go 1 inch per minute)
G1 F1 Z-.461(cut along Z axis to top of part at 1 inch per minute; go to -0.168 -0.293 = -0.461)
G1 F0.3 Y#4 (part off by feeding cutter to COR)
G0 Y-0.2 (move cutter away from stock)
G0 Z1.5 (retract quill so collet can be loosened and stock fed down)
G0 X#1Y#2 (move back to first cutter so COR is centered at point of right cutter)
M30 (end of program; rewind to start)

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