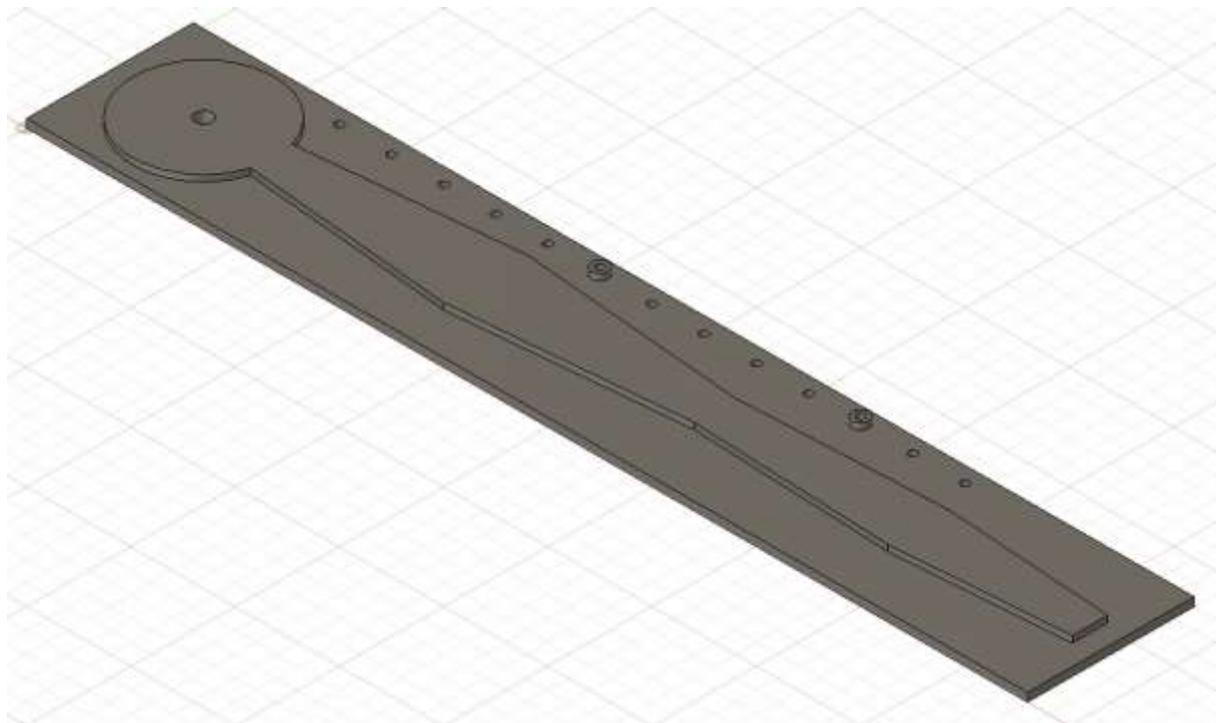


MILLING AN OBJECT OUTSIDE OF THE 440 TABLE FOOTPRINT

Introduction

This write up is not for the purists with years of experience but is an explanation of how I thought through how to machine something oversize that would not fit into my Tormach PCNC440 milling footprint. The overall operation would be split into parts. Hopefully this write up will help others to grasp the process.

The challenge began when a local turret clock expert came to me and asked if I could machine a new Hour and Minute Hand for a clock he was working on. The Hour Hand was around 14" long and the Minute Hand some 18" long. Here is the Fusion 360 view of the Minute Hand drawn on a stock backing plate.



Clearly an 18" length was way outside the 440 table X movement (10") so a plan was needed. There then followed a lot of staring into the distance at mealtimes and bedtime accompanied by vocal "hmmm"s as I tried to mentally visualise what was needed. This is one of my idiosyncrasies which my wife has come to terms with over the years.....

My conclusion from this mental preparation was that I needed to be able to accurately step the stock across the tooling table and then take two or three bites at the profile machining. What follows would almost certainly benefit from a video but sadly I am not set up for this.

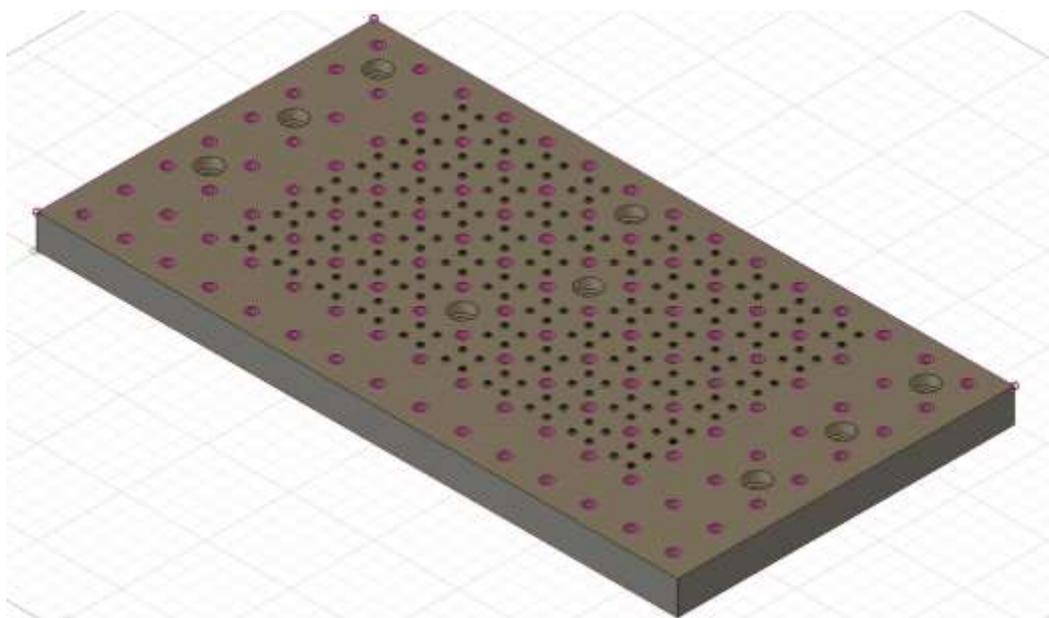
Input to Fusion

I decided to make the Minute Hand first as this was the longest and therefore the largest challenge. This is where I might raise some purist eyebrows but here are my steps :-

- 1 I chose an arbitrary size for a stock rectangle that would encompass the final Hand profile in XYZ. Let's go metric at this point 80mm x 480mm x 7mm.
- 2 I sketched the X and Y dimensions in Fusion and extruded this up for 4mm.
- 3 I drew a sketch of the Hand on the 'top' surface of the extruded rectangle.
- 4 I extruded the Hand sketch up for 3mm above the base rectangle to now give a Hand that was 7mm deep overall when cut down to the stock lower surface.
- 5 I extrude cut the Hand mounting hole at 8mm to match my tooling table hole size.
- 6 Down the side of the stock and outside of the Hand outline I placed a number of 4mm holes 25mm spaced. Not all these would be totally necessary but I wanted some positional flexibility as I moved the stock across the table and I was not sure at this stage what my offsets for each cut would need to be.
- 7 This completes the Model entry although it subsequently needed two edits which will be explained later.

It is important at this stage to explain that the following process is not easy to replicate unless you have a tooling plate with a healthy matrix of tooling holes (rather than just T slots). My tooling plate has M8 holes on a 25mm matrix across the whole area of the plate with 4mm clearance holes set within each 25mm square. These small tooling holes are only within the X and Y limits of the Tormach machining envelope. (This helps remind me of my limitations ..)

Here is a view of the plate showing the M8 holes, the 4mm tooling pin holes and the counter bored mounting holes to match the T slots on the 440 table. While I refer to the tooling pins as 4mm, the holes in the plate are 3.7mm so I could use 4mm silver steel rod for the pins with each having a 3.7mm turned shoulder.



My Tooling Plate showing the 25mm matrix and the 4mm tooling pin matrix

The Magic

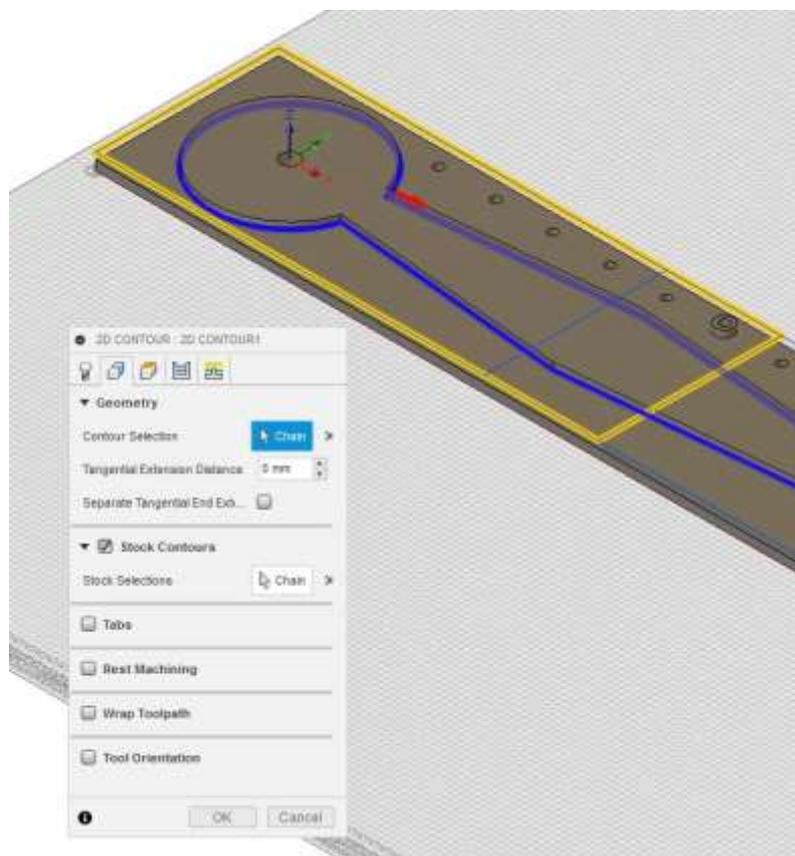
I now had the Hand sketched out which could be cut with a 2D profile if only I could cut 18" in X across the milling axis. What comes to the rescue is to break this down into 3 sections using Stock Contours. To do this you sketch boundary shapes to break down the job into sections. These are 'drawn' on the top surface of the stock. These are not readily apparent when viewing the model but are there to be picked up in CAM. The CAM accepts the full profile of the 2D shape of the Hand (using Contour Selection) but will only undertake to cut within the boundary boxes defined by the Stock Contours.

These two types of selection are slightly confusing. I regard Contour Selection as being a real tangible aspect of the design geometry whereas Stock Contour is an imaginary area relating to the basic stock. This can be the whole stock boundary or a section of the stock as defined by a sketch. I sketched three Contour Selection boxes to have arbitrary but overlapping dimensions sufficient to give me a number of the model tooling holes in each. Fusion codes the lead in and lead out of the tool automatically in each section of machining activity.

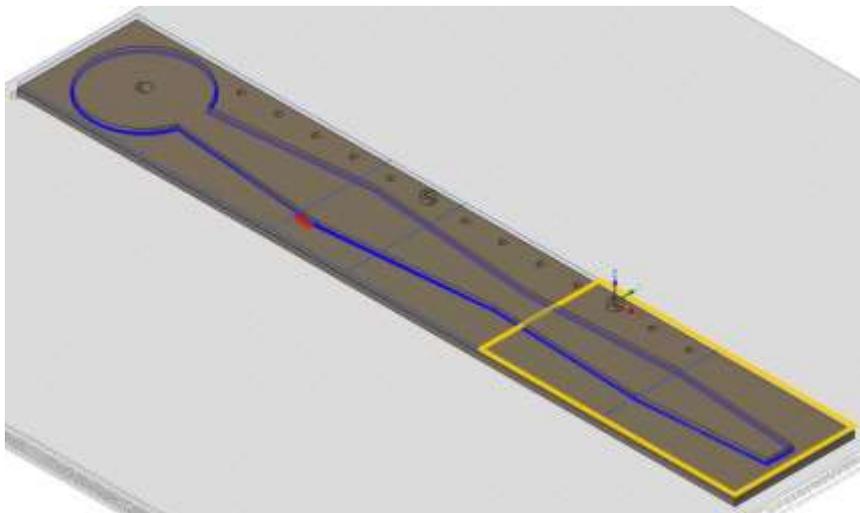
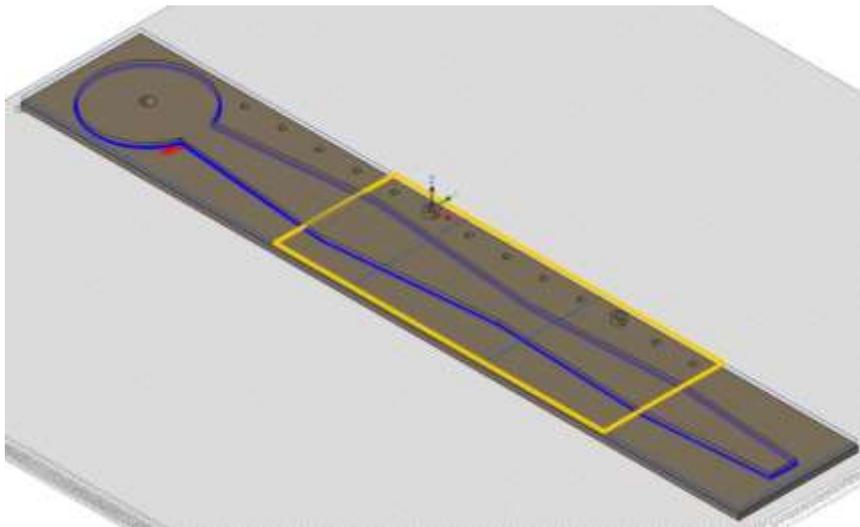
There is a good two part description here :-

<http://cadcamlessons.com/fusion-360-2d-contour/>

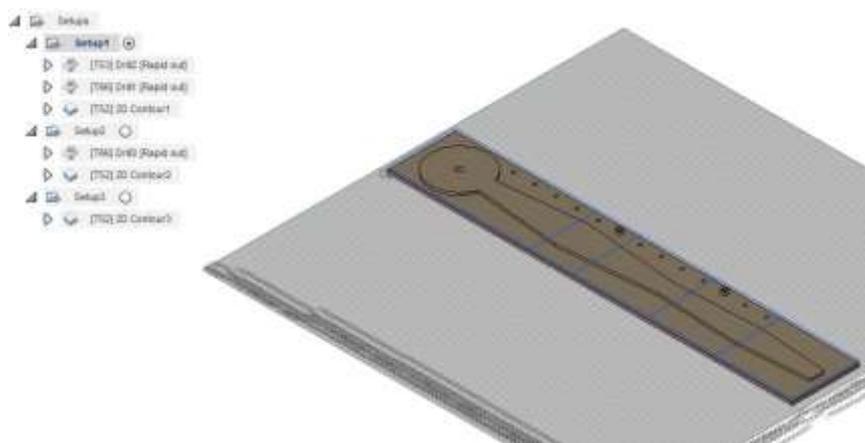
Each of these areas can be regarded as separate jobs and the mill has no knowledge of how they interrelate to each other. It is important therefore that they each have their own Set Up and XYZ reference point coinciding with an identifiable feature. This feature must be common to the particular Contour Selection area being machined and the previous section. The following images show the three sections and the Setups.



First Setup showing the Stock Contours tab and the outlined machining area



Setup 2 and Setup 3 showing the Stock Contour boundary boxes



Fusion 360 CAM showing each section operations

Mounting and Locating the Stock for the first Ops

I will try to explain this but you might have to read it twice, in fact you will probably have to read the whole document at least twice.

- 1 I mounted and clamped a length of brass bar at the rear of the tooling table and checked it was parallel to the X movements. This would provide a solid Y reference to work against when sliding the stock across the tooling table.
- 2 The first section to be machined would be the Hand boss end so it was necessary to decide which of the tooling plate M8 holes would be the centre hole of the Hand boss. To do this I loosely placed my stock onto the table up against the brass bar and jiggled it around to see which hole on the LHS of the machining footprint of the tooling table best matched. By having the stock width oversize I was not too limited in my choice.
- 3 Having chosen a particular tooling plate M8 hole as the Hand boss centre I now needed to make the spindle sit over this hole as X0Y0. I removed the stock and put my laser centring tool into the Tormach spindle. This has a laser diode offset from the spindle axis and when rotated by the spindle motor, creates a red ring of laser light on the object below. By moving the spindle up and down the size of the red light ring can be varied. This is a wonderfully simple but accurate way to set an object centre by eyeball. You can find details of this elsewhere on my blog. I moved the X and Y to centre the red circle on the chosen M8 hole.
- 4 When content that I had concentricity between the spindle and my chosen M8 hole I zeroed X and Y. I did a double check by manually moving the spindle to X32.5 Y32.5 which brought the laser over the first tooling hole I had sketched on the model. I rechecked concentricity once again and this looked very good. (An alternative method for this setup would be to use a Haimer or similar touch off probe).
- 5 I placed the stock with a sacrificial sheet under it on the table and clamped it in place and zeroed Z to the stock top surface.
- 6 I ran the first stages of CAM on Section #1 which was the 8mm clearance hole on the Hand central boss and the first six 4mm tooling pin holes.
- 7 I removed the stock and using the witness marks in the sacrificial under board I put sloppy clearance holes in this board to match the 8mm and the first 4mm tooling hole.
- 8 I dropped the sacrificial board back onto the tooling table over the tooling pin and then mounted the stock in place picking up on the first tooling pin and the M8 hole to locate it accurately in position. I fastened the stock in place with a M8 screw and various clamps. This combination of M8 and tooling pin locked the stock in place against the brass bar. The M8 hole was used as the first setup reference location. The tooling pin at X32.5 Y32.5 would stay in place on the tooling table and be used to reference the subsequent two sections of machining.
- 9 I ran the profile for this first section of the Hand with the CAM Heights tab set as cutting from Stock Top to Stock Bottom -1mm. This would ensure a full cut through the stock into the sacrificial board.



General View of my Laser Centring Device



Laser Centring Tool in action showing the 'aiming' red circle and the tooling pin



The stock and sacrificial board clamped in place against the rear Y reference brass bar

Second Section

- 1 I demounted the stock and moved it to the left across the table so that the tooling pin in the table now located in the sixth tooling hole drilled along in the stock (this turned out to be the best location to maximise the machining envelope).
- 2 Knowing the geometry of the tooling plate I manually moved the spindle once again using direct GCode inputs to X32.5, Y32.5 and then zeroed the X and Y at this position. This was dead centre of the tooling pin I had chosen to use as the stage 2 reference.
- 3 Problem – I wanted to use this pin as X0Y0Z0 which was fine for X and X but Z was wrong on the model as this was sat at 4mm, not 7mm. I edited the model and created a boss around the hole and extruded it up 3mm to give me a model Z zero that was now correct. This explains the boss around this hole and on the eleventh hole for the third section.
- 4 I ran the first operation in this setup which would give me more tooling holes as a choice for the third section and then ran the 2D profile of this middle section profile of the Hand.

Third Section

- 1 No more tooling holes were needed to be drilled in this section as the previous operations had created enough to choose from. The eleventh hole looked the best placement fit for maximum X machining length and the stock was placed over the tooling plate pin. This was still X0Y0 from the previous operation. This hole on the model also needed me to sketch and extrude a boss around it to correct the Z height.
- 2 Once Z was zeroed, the only machining operation in this set up was the final Hand profile and this was run to complete the job.



Almost there – running section 3 profile of the Hand

Note that care is needed to ensure that both the Hand and the cut away stock are firmly clamped or bits will break and fly as breakthrough depth is achieved. In the above picture I have already removed some of the 'floppy' bits.

Final Result

The machining of the Minute Hand has worked to my plan with a lot learned in the process. The continuity entry and exit tool witness marks from each individual machining section were minimal. On an object this size and mounted so far away from people it would have been of no consequence.

I am quite pleased with how it has turned out. A repeat of this process is now needed for the Hour Hand.



End result showing the final finished clock Minute Hand