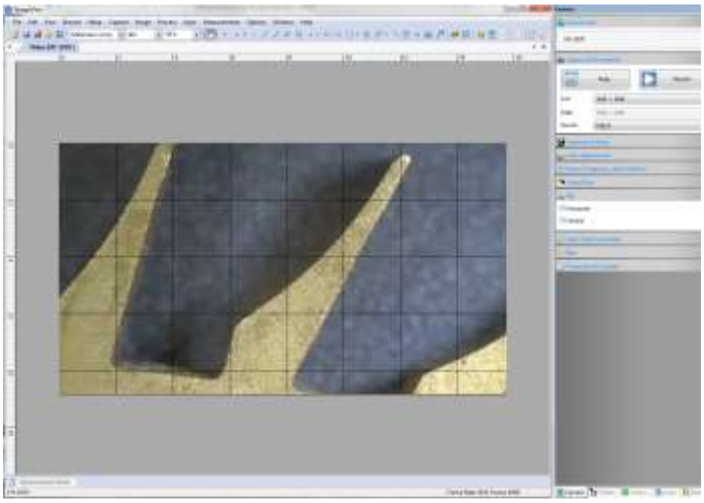
CUTTING A BROCOT CLOCK ESCAPE WHEEL USING CNC

This write up follows my thinking and process in producing a Brocot escape wheel using CNC techniques. The Brocot wheel is not a straightforward tooth profile that would lend itself to using a fly cutter on an indexing mechanism. Instead two cutters would be used, one for the curved section and one for the notch. These cutters are available from PP Thornton but are expensive to buy.

The wheel in question was to replace a 30 tooth wheel of some 77mm diameter that had come out of a turret clock. Some of the teeth were chipped and bent and it had seen better days.

Drawing the Profile

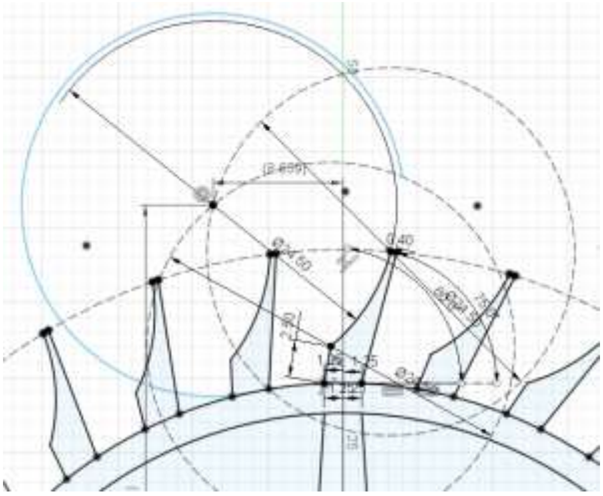
The first task was to measure the wheel dimensions and get this transferred into Fusion 360. This would have been impossible to do without my microscope which has PC viewer with inbuilt measurement facility called Image View. You have to calibrate the viewing screen area against a known length object and once done you can measure lengths, curves and angles. This is incredibly good value for such a low cost item and is indispensable in an engineering workshop.

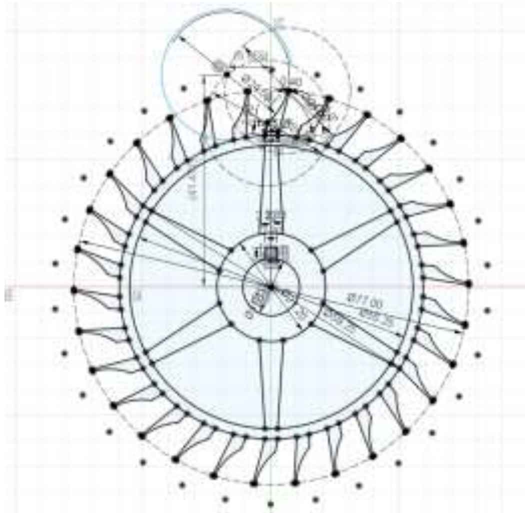


https://www.amazon.co.uk/gp/product/B07VL44TJT/ref=ppx_yo_dt_b_search_asin_title?ie=UTF8&psc=1

Fusion has the ability to create a circular pattern so I only needed to carefully measure one tooth on the wheel and then propagate this around the wheel circumference. Using the information in J Malcolm Wild's book (Wheel and Pinion Cutting in Horology) I noticed that my sketch of the tooth curve was not dissimilar to the geometry of the PP Thornton 7E cutter. Malcolm's book gave me the arc radius for the 7E and this helped fine tune the shape I had created from microscope inspection.

Here are some of the Fusion sketch views. Having got the profile drawn it could be extruded to 5.5mm thickness ready to create the CAM program for my Tormach PCNC440.





Creating the CAM

This is where things got a little difficult. All the things I thought I knew about CAM didn't seem to work. I sought advice from John Saunders at NYC CNC and he pointed me in the right direction. Using a 3D Adaptive strategy seemed to look as if it would produce a result.

To try out the model I did a trial run as a 3D Adaptive on a block of 6mm cast aluminium. I only cut to 3mm depth so there was no breakthrough to plan for. The result was a very good match against the original wheel profile. Here is a picture of the result with the top surface blackened with a Sharpie pen.

In theory all was now good to go but some planning was going to be needed. The brass would need to have a sacrificial backing plate and would need to be held firmly to this once breakthrough occurred. The sequence of machining and the referencing of the mill would also needing thinking about.

I struggled yet again to make Fusion give me the separate sections that I wanted to work on using a 3D Adaptive process. I also found that Fusion was creating some huge GCode results. My simple minded solution was to do a number of Save As copies of my master drawing and then edit them to just the geometry I was interested in for each machining activity. Long winded but safe.

Planning, Sequencing and Running

The finished wheel diameter was to be 77mm so I opted for a stock and sacrificial plate size of 80mm x 80mm. The sacrificial backing was to be the same 6mm cast aluminium plate. Cast aluminium is nice to machine and is flat, uniform and stable.

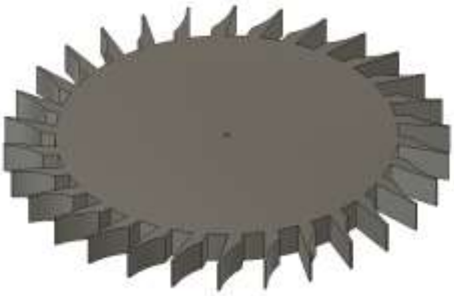
The sequence was as follows : -

1 Mount the brass plate in the vice on the mill and face off the top and bottom sides to bring the overall thickness to the finished wheel thickness (5.5mm). Probe for the centre of the plate and drill a 4mm central clearance hole. Remove from the mill. Note that the brass plate could be square or circular. Using a circular plate saves some machining time and wastes less material.

2 Mount the sacrificial plate on the mill and probe for the centre. Mount the brass plate central on top of the sacrificial plate and clamp in place with two toolmakers clamps. Run the backing plate CAM operations. This consisted of a number of super glue arbor troughs, corner mounting holes (4), petal mounting holes (6) and centre hole. Mark the brass plate so you know the orientation and remove from the sacrificial plate. Rub down the top surface of the sacrificial plate with a fine abrasive stick but leave in place on the mill in the vice so you don't lose the referencing.

3 Degrease the top surface of the sacrificial plate and the brass plate. Drop seven M4 x 15mm screws in the holes in the petal and centre holes. Apply SuperGlue to the top surface of the aluminium and lower the brass plate into place using the seven screws as a locating reference. I did not fit nuts on these at this stage. Put a heavy weight on the top of the sandwich and leave the SuperGlue to go off.

4 Once the glue has set, fit nuts to the seven screws and clamp down tightly. The first operation can now be run on the teeth. I did three operations. An adaptive clearing using a 6mm end mill followed by rest machining using first a 3mm end mill and then a final 2mm end mill to get down into the tooth trough. Run time overall was 2 hours at my conservative depth and width of cut and my speeds and feeds. All cuts were to 5.575mm depth to just cut into the sacrificial plate.

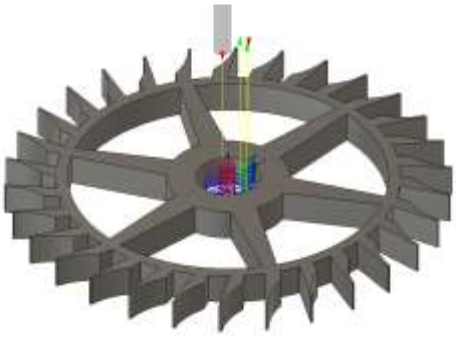
 

5 My next choice of operation was to mill the petals. With hindsight this was the wrong order. I should have milled the centre hole and keyway notch first. I could then have made a button to fit the central hole and re-clamp the wheel. Hindsight is wonderful.

That aside I was uncomfortable removing the 6 petal screws leaving only the central hole screw to grip the wheel together with the SuperGlue. I opted to make a 3D printed frame to sit over the teeth. This picked up on the four corner screws in the sacrificial plate and had a thin rubber ring to grip down on the teeth. Once this was fitted I removed the six petal screws and ran the petal removal operations – a 6mm 2D pocket and a 2mm rest machining.

6 All that remained was the central hole … but now my clamping options were totally dependent on the 3D printed outer frame. A quick new 3D print of a ring to fit into the petal area and pick up on the petal holes in the aluminium backing plate solved the worry. This ring really pulled down on the wheel so it was going nowhere fast. The centre hole could now be run with a 3mm pocket and a 1.5mm rest machining of the keyway.



7 Job done. Removed all clamping and a gentle rub of both sides of the wheel on 2000 grit to remove the edges. Very pleased with the result and very relieved to finish it without any dings. Considering the day before we had had two power outages I think it is time to get a UPS for the Tormach.