Making a Tourbillon Pocket Watch

Experiences of a Non-Horologist

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Late in 2013, as the nights were drawing in, an article on the BBC website caught my eye that signalled the start of quite a journey. There was something in the title along the lines of 'the world's greatest horologist'. Intrigued, the link was opened revealing the outline of a man then new to me, George Daniels. That one man could make all the parts of a watch from raw materials was a revelation and also seemed to be suggesting something of a challenge. As the saying goes 'what one can do so can another', if determined enough.

While having no background in horology, I was once a toolmaker and had made a few small working models in the past. However, making miniature copies of life sized machines that already existed was not particularly satisfying for me. The realisation that it might be possible to create a small mechanism that was functional, useful and attractive was a different matter altogether – a case of 'each to his own'. That Christmas morning a copy of *Watchmaking* arrived, courtesy of my wife, and so began the wonderful journey that continues to this day.[1]

A conscious decision was made to focus on making a functioning movement to the design of Daniels: nothing more and nothing less. A perfect black polish could wait for watch number two, there being no point in finishing a part to a high standard when it may not perform as expected, if at all! The same approach was taken to the mechanism as a whole: no complications, no temperature compensation etc. Again, the thinking being that once a basic movement with a functional escapement could be made it would be possible and more importantly worthwhile to address these deficiencies. I firmly believe that this focused direction has been the most important factor in being able to make a working pocket watch movement, **Figure 1**.

In *Watchmaking*, Daniels refers to the 'Cork and Nail' method as a way of describing what the manufacture of a watch by hand means with crude tools. Encouragingly, he also points out that while sophisticated machinery is a great help, it is not essential to the making of the various parts of a watch. So, an old Unimat 3 lathe was retrieved from the garage and refurbished as best as possible.

The first major task was to devise a method of cutting gears. While designing and making a dividing attachment for the headstock of the Unimat was fairly straightforward, the standard milling capabilities of it are not particularly satisfactory. The barrels were cut purely on the lathe with the Unimat milling attachment on the cross slide, though in all honesty this was not rigid enough. In an effort to improve matters, all the other wheels and pinions were cut by clamping the Unimat to the table of a larger bench mill which was found provide a far more satisfactory outcome, **Figures 2 and 3**.

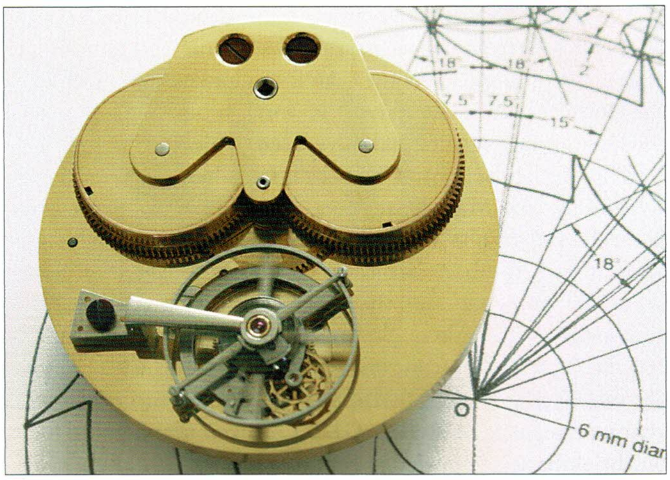

Figure 1. The completed movement.

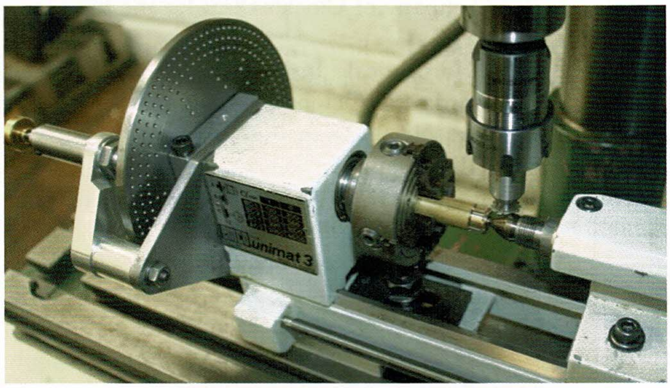

Figure 2. Cutting teeth on fixed fourth wheel using the refurbished Unimat 3 lathe.

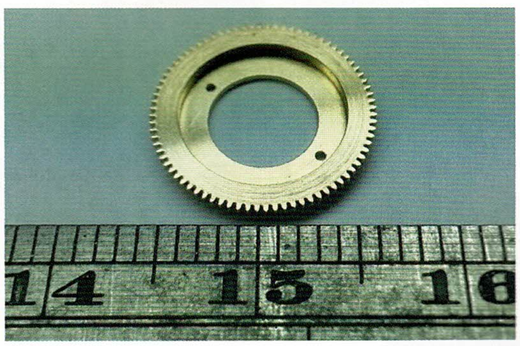

Figure 3. Finished fourth wheel.

The lathe then acts as a self-contained dividing head with integral tailstock.

Figure 4. BCA jig borer and custom made centring microscope (based on Hemingway kit).

With the barrels made you soon realise that there is no escaping the need to make a couple of very small screws to secure the star wheel of the Maltese-cross stop work. This was the first of many requirements that were well outside the experience of a tool-room apprenticeship and often required several attempts and more than one re-think. For example, machining sub-millimetre diameters requires a well-sharpened and honed lathe tool that is spot on centre height.

The whole process of making a first watch has shown that it is best to treat each new challenge as a learning exercise and not to expect the first part to be correct. This was a big change, as when working at 'normal' sizes it was considered a bad day in the workshop if a second part needed to be made, let alone several to get things right!

As well as treating each challenge as a learning exercise, it also helps to think about the repeatability of any process, such as from simple tool sharpening to the machining of a complex part. It is always easier to do the right thing if the facilities are to hand. For example, having a second bench for all tool sharpening and heat treatment work has saved time as well as reducing the chance of cross-contamination. The actual facilities do not need to be grand, but taking the time to ensure that everything required is conveniently laid out makes all the difference. Watchmaking needs all the patience and concentration that you can muster; you don't want to waste any of that precious resource hunting for things.

Another valuable lesson has been that time spent making tools and jigs really is time well spent. It is always tempting to push ahead with some basic (dare I say crude) lash-ups to keep things moving, to make the next part. A lot of time fiddling around in the early stages would have been better spent making good quality tools. The making of good tools and equipment is an investment for the future: the next job will get done a lot quicker and the results will be assured. This was fully brought home when making the balance roller. I had chosen to make the watch with a Daniels' Co-axial escapement and the balance roller has a pin and an impulse pallet that need to be precisely located relative to each other.

Making the 'D' for the pin provided a lot of 'entertainment' over more weeks than I wish to admit, not to mention manipulating the pin into the hole once made! This was the first component which, for me, meant a departure from the methods outlined in the book. For example, Daniels suggests drilling a small hole (0.4mm in my case), making a replica of the impulse pin in hardened steel, placing it in the hole and giving the outside rim of the roller a tap to close the hole. This did not seem controlled enough for my liking, particularly given the proximity of the slot for the impulse pallet. To address this, special tooling was made to hold the dummy steel pin in the correct orientation. Rather than using a blow from a small hammer the correct spot was crushed by a screw correctly located in the same jig. Making this feature is now a reasonably straightforward and controlled job – time well spent.

The expectation was that once the balance roller was completed it was just a matter of making the lever, assemble all the parts and the watch would tick. Surely making a lever could not be that difficult after the challenges of the roller? Well not quite, and a separate article could probably be written covering the manufacture of the lever, filing the horns to shape, setting the locking pallets, making the safety dart etc. This was the second component that threatened to bring the whole project to a grinding halt. The next couple of paragraphs outline some of the approaches used in the hope that they may be useful to others.

Watchmaking details the geometry of the Co-Axial escapement and tells you how to draw out the mechanism to a large scale from which dimensions can be taken. A method of marking out the lever is then suggested which looks reasonable enough on the page. However, it became clear within five minutes that my abilities to mark out accurately and then drill the required holes in a rather small piece of steel were just not going to happen.

A different approach was needed if the making of this part was not going to be a show stopper. In an ideal world a small jig borer would have been acquired from day one, however this was not possible at the time so best use had to be made of the nearest equipment to hand. This was a small mini-drill complete with a not very accurate compound table. A couple of brackets were machined up so that dial gauges could be fitted to the compound table. These would be used to correctly position the slides for the key drillings and this served for the first few attempts at making the lever. The watch even ticked with one of these early versions at the beginning of 2016, though very unreliably and more by luck than judgement. Encouraged by this progress a better solution was sought.

The better solution entailed spending a number of months refurbishing a BCA jig borer and designing a new spindle based around precision angular contact bearings, **Figure 4**. Fittings were also made to attach Mahr digital dial gauges to the X and Y axes. The BCA, together with some additional tooling, made the manufacture of the lever far more certain and quicker, **Figure 5**. It will also enable much better tooling,

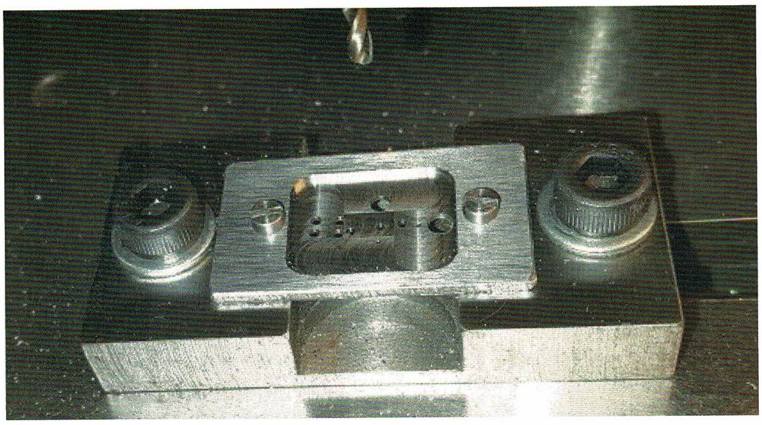

Figure 5. Embryonic lever No. 12. Drilling the final 1.7mm clearance hole for holding down screw for subsequent operations after cutting out.

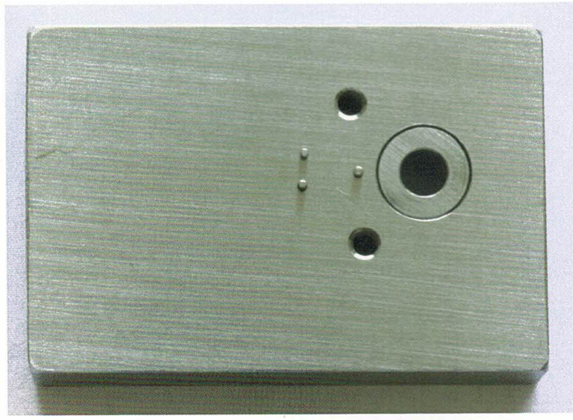

Figure 6. Lever horns filing jig.

wheels, pinions, etc. to be made for subsequent watches.

With the basic manufacture of the lever resolved, the final challenge in making this part was shaping the horns correctly. It was difficult to find any references on how to shape the lever horns to interact with the roller pin correctly. *Watchmaking* makes it clear that the shape of the horns is important but does not seem to suggest a method to generate the required shape. After a number of failed attempts at filing free-hand the 'toolmaker' took things in hand and came up with a filing jig, **Figure 6**.

The filing jig is essentially a replica of the key geometrical points on the tourbillon carrage, that is banking pins, lever pivot and balance pivot. Centred on what would be the balance pivot point is a hardended steel filing button held in place from the side by a small grub screw. The internal diameter of the button being machined to the radius that the roller pin describes. To allow for any possible tolerance build up the centre distance between the lever pivot and balance/filing button was made 0.015mm greater than that on the carriage. Final sizing was made with the lever assembled in the actual carriage.

The jig is also used to ensure that the 'tail' of the lever is central to the overall geometry. This is achieved by placing a pin in the filing button which aligns the lever centrally by locating in hole A, **Figure 7**. As the 'tail' is filed by hand there is a chance that this will be slightly off centre which needs correcting before the horns are shaped.

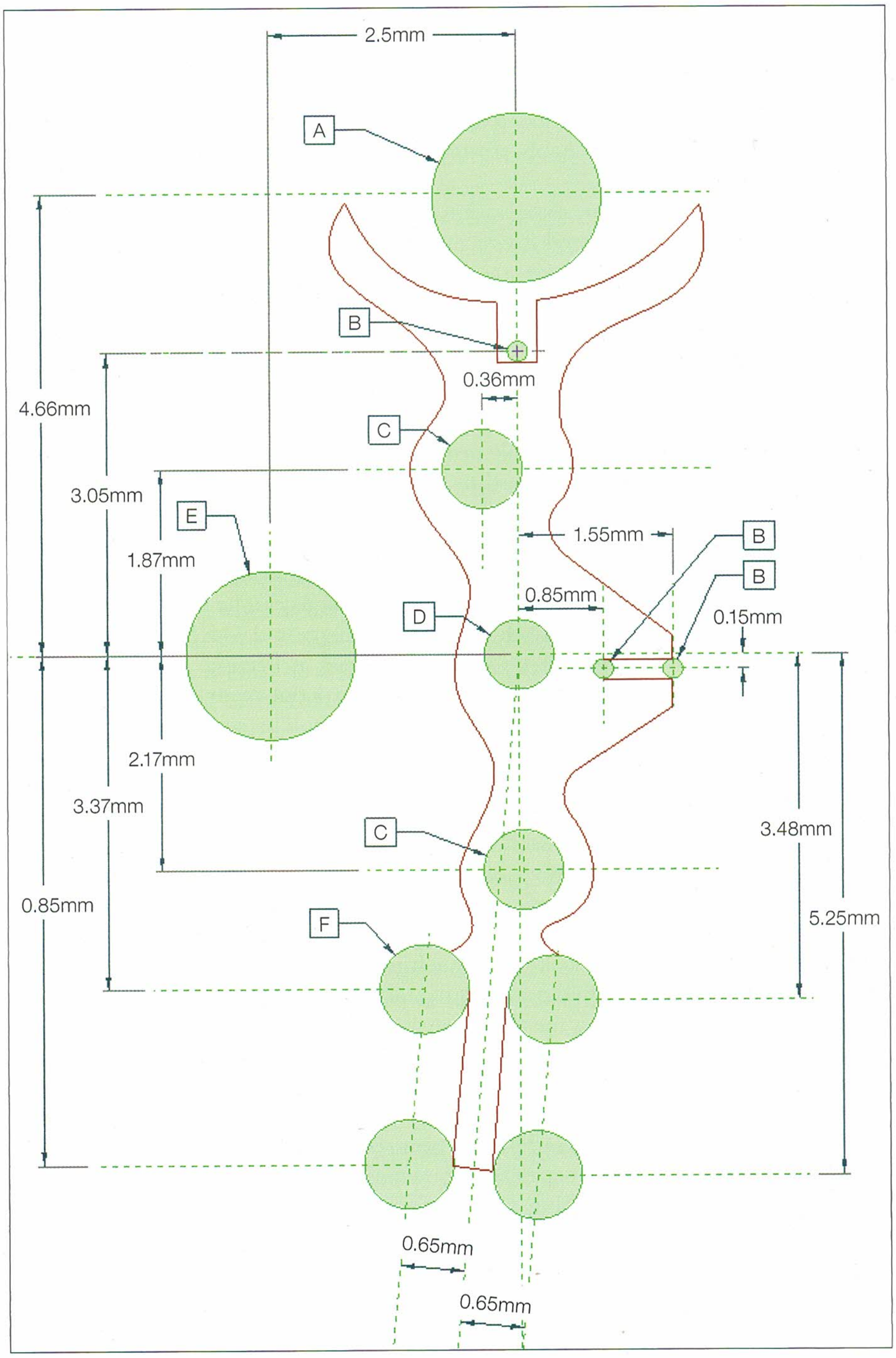

Figure 7. Drawing of lever - see table, **Figure 8**, for additional information.

Reference	Diameter	Notes
A	1.7mm	Alignment hole. Used as a reference in the lever jig to ensure the tail is central before filing the horns to shape.
B	Spot	References for depth of slots.
C	0.8mm	For locking pallet holders.
D	0.7mm	Pivot staff holes.
E	1.7mm	Clearance hole for securing screw in slotting jig (not covered in this article).
F	0.9mm	Guides to assist in determining the limits of the lever tail.

Figure 8.

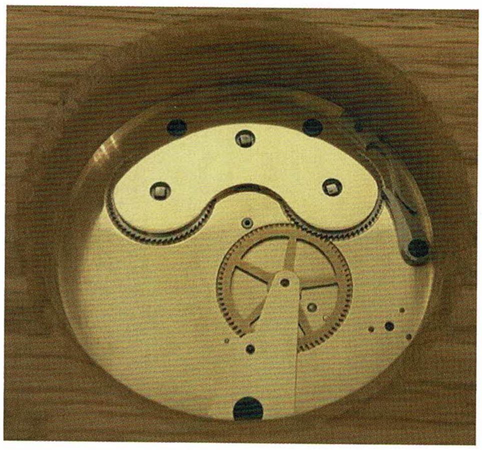

Figure 9. Under-dial view, awaiting motion work.

Once any adjustments for alignement have been completed, the lever is moved hard against one of the banking pins and clamped in place by a strap and two screws (hence the two holes in the steel block, which are tapped). It was found best to partly complete each horn in turn by removing around 80% of the material before finishing to size down to the button.

The lever went through a number of iterations before errors in interpretation of geometry as well as making were ironed out. Eventually, version 12 was fitted to the movement and finally it ticked in a much more satisfactory manner, and continues to do so today.

At this point you may be thinking what about jewelling, burnishing pivots, making escape wheels, forming a terminal curve and a myriad other operations. Yes, they have all required their fair share of effort and like everything else need further improvement. For example, all the pivots, including the balance staff, were machined in the lathe as if they were of a more normal size – not a graver in sight! By the time this article is published a course will have been attended at Upton Hall covering graver turning to address this area. However, nothing comes close to making that lever!

Readers may also be interested to know that while this project was driven mainly by the writings of George Daniels, a second George has been an invaluable mentor. Some members probably have equipment that they have either purchased or made themselves based on the designs of Geo. H. Thomas.[2] There is much to be learned from his approach to designing tooling and general problem solving at the small scale.

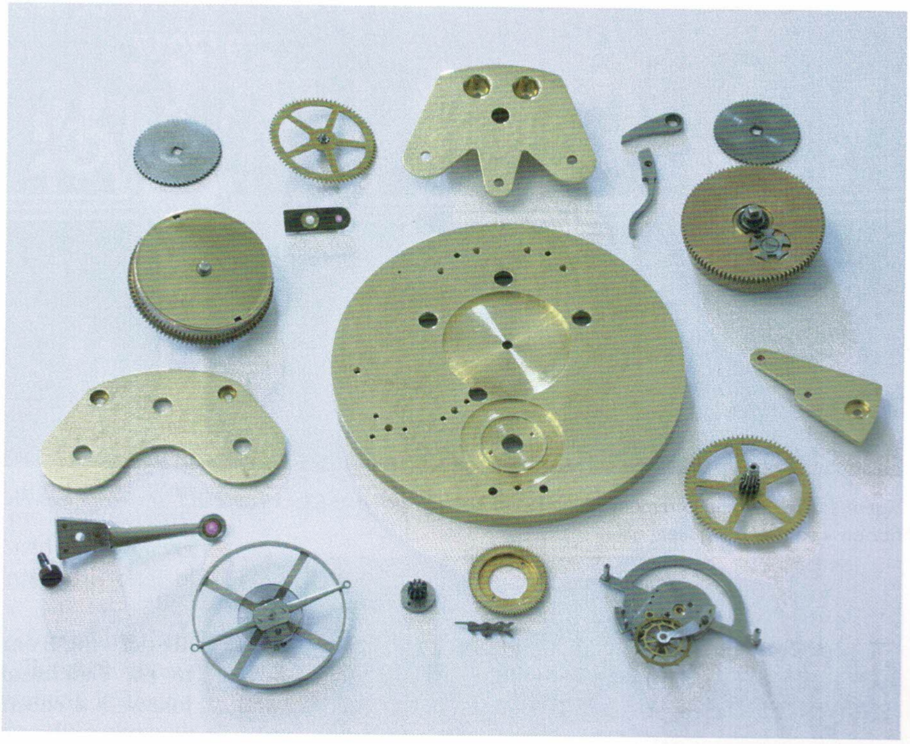

Figure 10. The completed componenets of the movement ready for assembly.

Now that the basic movement works correctly the next step is to make a suitable dial, **Figure 9**. This will be engine turned in silver and I thank John Moorhouse for his invaluable help in this area. As things currently stand the preferred option would be to acquire a straight-line engine. Given that such machines are rare, a design for a purpose-built machine for dial making is in hand. This will combine the capabilities of a straight-line and rose engine based on the concepts devised by John and has been christened a 'Straight-Rose Engine'. Whatever the outcome, once the dial and case have been made, Part 2 will follow in due course.

Acknowledgements

John Moorhouse, for kindly making useful suggestions during the preparation of this article.

ENDNOTES

1. G. Daniels, Watchmaking, (London: Philip Wilson Publishers Ltd, 2015).
2. George H. Thomas, Workshop Techniques, (Leamington Spa: TEE Publishing Ltd, 1998).