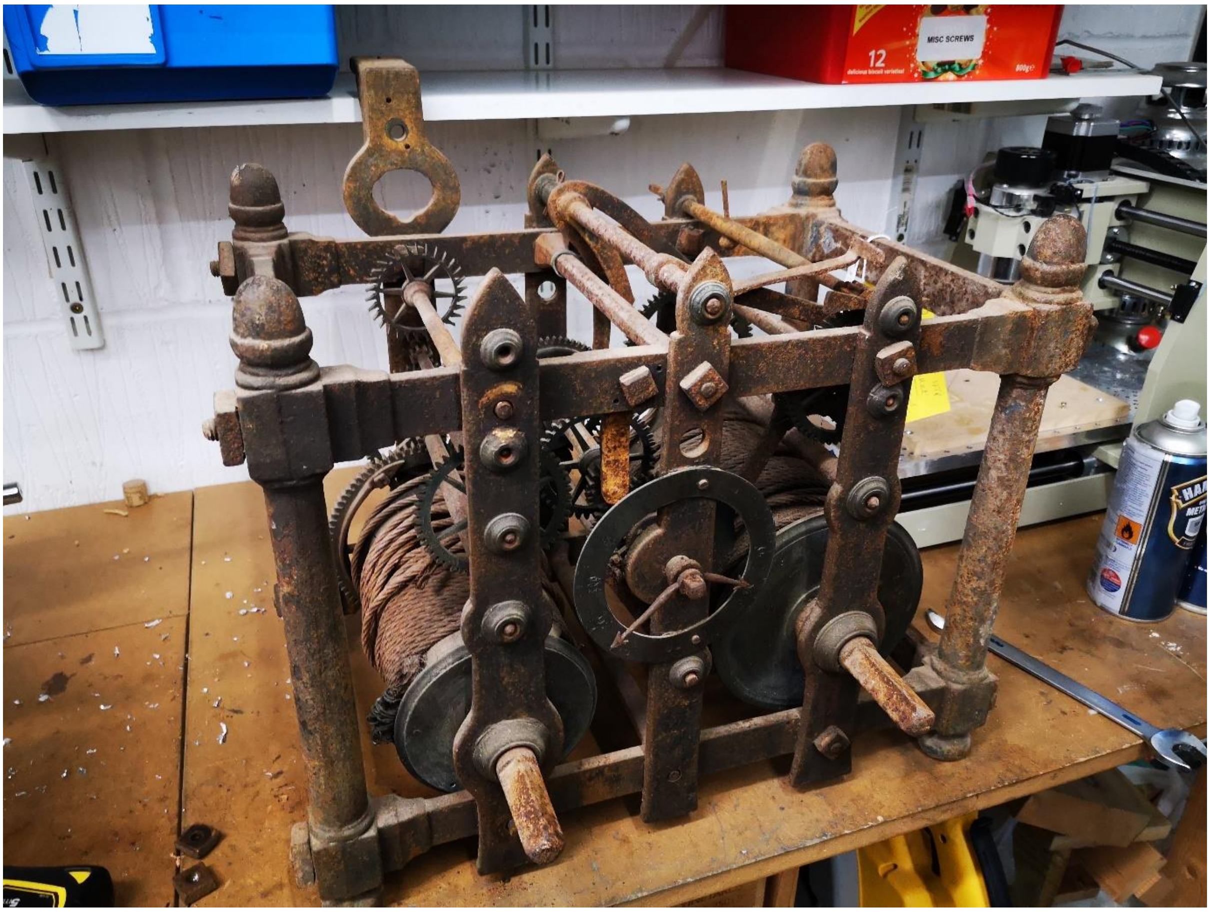
THWAITES CLOCK PARTS REBUILD ACTIVITIES

Introduction

I was contacted via my blog by an overseas reader. He had bought an ancient turret clock from a UK recycling company. The clock was going to need some TLC before it was shipped out to him. The clock appeared to be a Thwaites design and was in a very poor rusty condition. He had found my blog entry describing a new escape wheel I had cut and he believed his clock was very similar. His clock was known to have had a recoil escapement (also known as an anchor escapement).

The clock duly arrived and was missing the suspension spring, pallet arbor, pallets, crutch and pallet arbor mounting bracket. The escape wheel was present but it was damaged. The image below gives a good impression of the condition.



After discussion with the client, I undertook to produce these missing parts, all of which related to the timekeeping section of the clock. I was not intending to undertake any work on the chime section. My challenge was to get the clock 'ticking'.

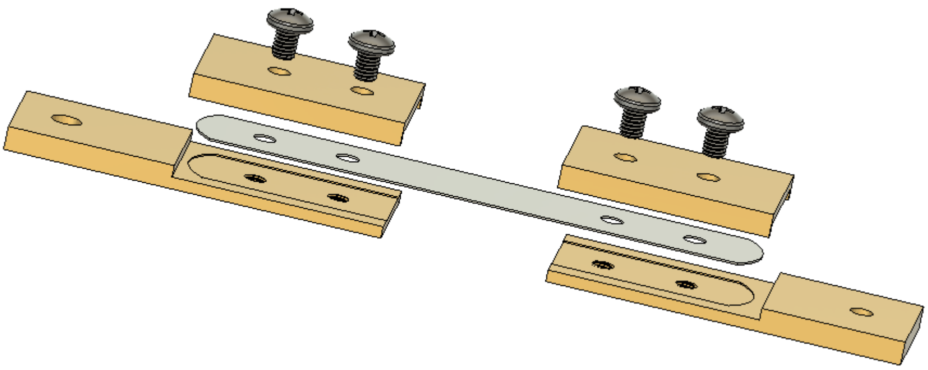
Components

The following notes detail the activity on each of these missing components together with Fusion 360 screen shot images of each part as modelled.

Suspension Spring

The pendulum as received had a rusted piece of metal in the top fork suspension point.

There was therefore no reference as to what form the suspension components might take. Based on previous experience I opted to make two brass sandwiching clamps that would hold a piece of spring steel. Here is the Fusion 360 model.

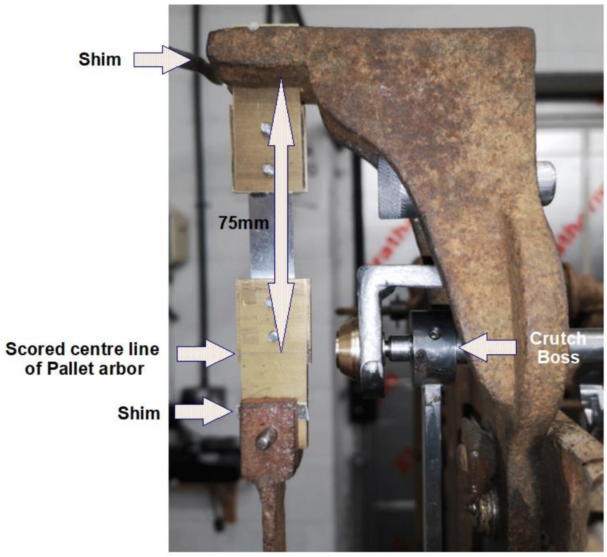


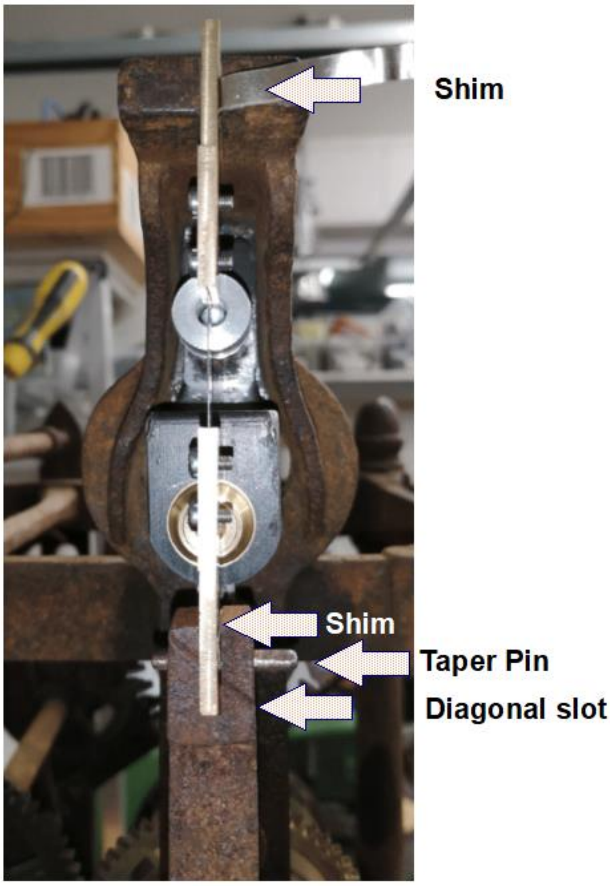
Subject to pendulum weight the suspension spring should be 10 to 20 thou thickness. Spring strips of ½" width are produced by SPI and can be bought through MSC Industrial. I decided on a 2" exposed length between clamps. The clamps would be held together with two M3 clamping screws in each clamp. I made two versions of the spring in different thicknesses, one in 12 thou and one in 20 thou.

I tried this assembly on the clock I noticed that both thicknesses of spring strip caused too much side twist leading to a circular motion on the pendulum.

I reduced the exposed length to 1" between the clamps and this solved the circular motion effects but it now seemed too rigid in the 20 thou version. I decided that going forward I would focus on the 12 thou version. This decision seems to have worked out to be the best choice.

The top mounting block on the clock required a cross pin through the top suspension clamp and this sits in a groove on the top surface of the pendulum mounting block. The pendulum rod top fork has a similar slot and I dimensioned the lower suspension spring clamp to sit in this slot and used the original taper pin through the clamp. The following images show the pendulum suspension spring assembly in place. Note that the clamps were both slightly undersize within their respective slots and needed shims to stop any unwanted sideways movement of the suspension spring assembly.

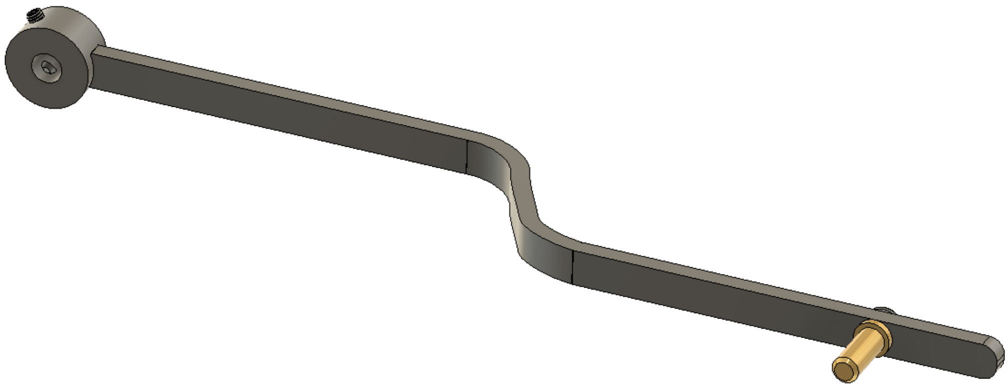




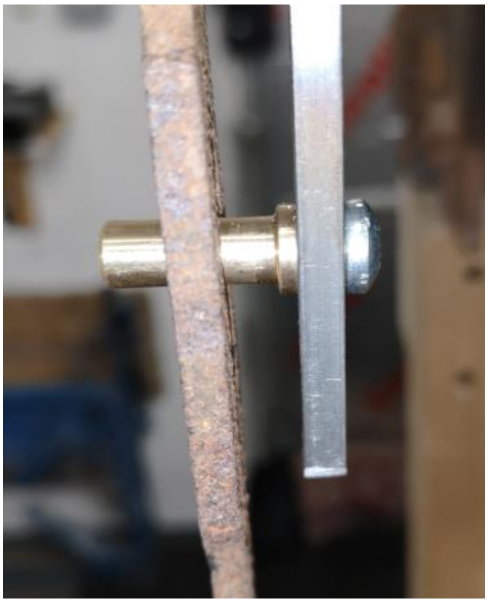
Crutch

As with other parts there was no reference available regarding the size and shape of the crutch. The design was therefore a best estimate of the geometry.

The crutch produced consisted of a shaped steel arm (10mm x 5mm) with a 22mm diameter steel bush for mounting on the pallet arbor and a pin to act on the pendulum. Here is the Fusion 360 model.



The 7mm crutch pin was a good fit into the existing slot in the pendulum. The fit may degrade once the pendulum is renovated. If this is the case a new pin will need to be turned to make a better fit. Prior to shipping to the client, the pin was held by a single screw and did not have Loctite applied. Once the final fit has been checked by the client after renovation, the Loctite should be added.

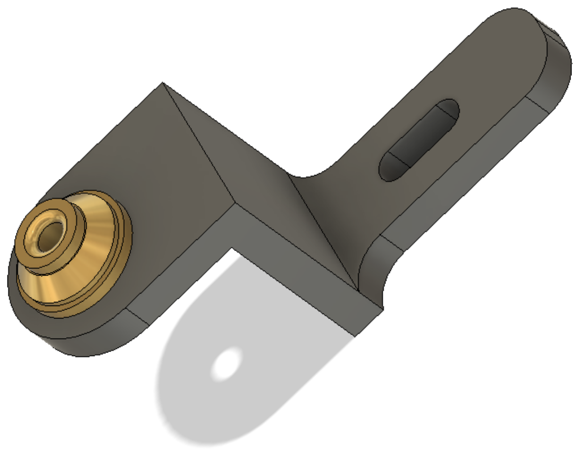


The crutch arm has purposely left with excess length at the crutch pin end. This would allow alternative holes to be made to move the crutch pin up or down relative to the pendulum slot.

The crutch boss which mounts the crutch assembly on the pallet arbor was turned from steel and silver soldered to the crutch arm. The boss has two M4 grub screws to give a good grip on the pallet arbor. There is a matching groove in the pallet arbor to accommodate the ends of these screws to stop distortion of the arbor surface which otherwise would make any later removal of the boss difficult.

Pallet Arbor Mounting Bracket

As with other parts there was no reference available regarding the size and shape of the mounting bracket. The design is therefore a best estimate of the geometry. Here is the Fusion 360 model which includes a new brass mounting bush for the pallet arbor.



The Fusion image above is somewhat better than how the part ended up and it is not one of my better constructions. That having been said it is functional and perhaps dare I say more in keeping with the rustic look of the clock.

The bracket has been made from a piece of steel which had been mitre grooved on the bend points and hot bent. The two resulting right-angle joints have been TIG welded. The brass mounting bush was turned on the lathe and finished to shape using a graver. The finished bush is held in place in the bracket with Loctite and carries the pallet arbor.

A slot (as shown) was cut in the bracket to allow the mounting position onto the clock frame to be moved. This allows adjustment of the alignment and positioning of the pallet arbor. The slot was cut excessively wide and this meant that the mounting position has a wide degree of location. In practice such a bracket should only allow an 'up' and 'down' movement to allow depthing adjustment of the engagement of the pallets and escape wheel.

The positioning of the bracket to give the correct spacing of the pallet arbor / bush to the escape wheel arbor is described later.

Pallet Arbor

As with other parts there was no reference available regarding the size and shape of the pallet arbor. The design is therefore a best estimate of the required geometry and the Fusion 360 model is shown below.

The arbor is manufactured from a length of 14mm diameter silver steel rod. A standard 333mm length of silver steel was just long enough for this. The ends of the rod were turned down to match the existing arbor bush at the winding side of the clock and the newly made brass bush in the pallet arbor mounting bracket. The diameters of both pivots are circa 5mm. Both pivots allow a nominal 5-degree angular float. The pivot ends are shaped and have a centre indent. The transitions shoulders are also shaped. The pivots have both been burnished.

The arbor has an 8mm section that accepts the crutch boss and the boss abuts a step shoulder transition to 10mm on which takes the pallet mounting. As mentioned earlier there is a groove in the arbor to match the position of the crutch boss grub screws to prevent surface distortion.

The 10mm section of the arbor is dimensioned to accept the pallets. The pallets have a 10mm central hole with two diametric M2 clearance mounting holes. These holes match M2 tapped holes in a boss that slides onto the arbor and abuts a shoulder. Two M2 cap head screws pass through the pallets and fasten into the boss. The boss has a single M4 grub screw for locking the position of the boss and in turn the position of the pallets on the arbor.

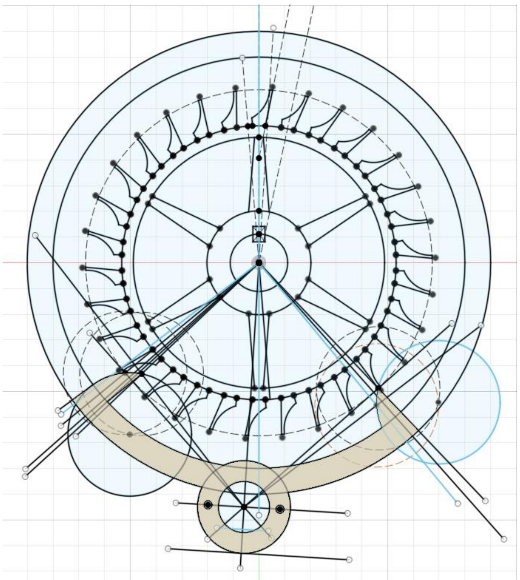
The use of a single grub screw is not sufficiently firm for long-term fastening of the pallet retaining boss. The constant pressure pulses from the escape wheel cause this. The recommendation to the client is that once final assembly is undertaken, then this boss should be bonded to the arbor either with Loctite or preferably by silver soldering in place. All adjustments of the pallet rotational positioning will then be by adjusting the crutch axial position on the arbor relative to the pallets.

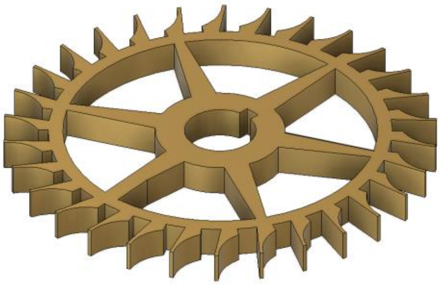
In a similar fashion to the crutch grub screw groove, there is a groove on the pallet arbor to match the position of the grub screw in the pallets bush. This will help negate distortion of the arbor surface to more easily remove the pallets or the boss prior to final assembly.

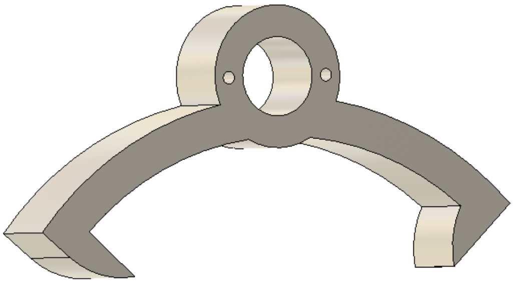
The client expressed a wish to aesthetically shape the arbor prior to final assembly. The construction as described allows the crutch, pallets and pallet boss to be removed for this to take place. Turning on a lathe for shaping can be done between centres using revolving centres mating with the end pips on the arbor end faces. Clearly care will be needed not to undermine the shaping of the pivot shoulders or the shoulder that positions the pallet locking boss.

Escape Wheel & Pallets

The clock arrived with the original escape wheel fitted. Using this as a reference a 3D model was created in Fusion 360. After interactive comparison between the drawing and the actual wheel, a good match was achieved. Having created the wheel geometry, the pallet geometry was derived and a 3D model also created in Fusion 360. This allowed the match to the wheel geometry to be checked. The Fusion sketch and models are below.





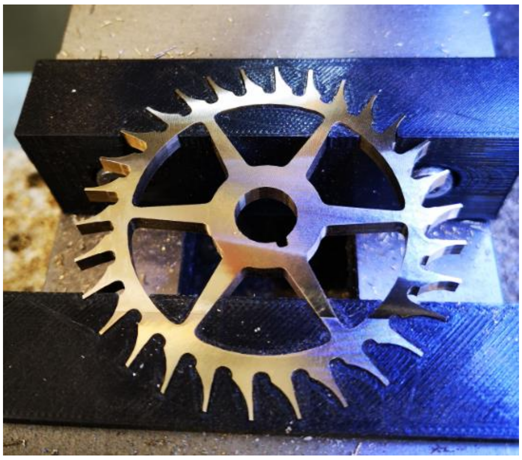


The Fusion modelling looked positive and a set of pallets were then CNC machined using 10mm Ground Flat Stock. The stock for this was cut as a rectangle and was held in the machine vice by 1mm of material sat on parallels. On completion of the top side CNC operations, the workpiece was turned over and held in a set of 3D printed soft jaws while the residual stock was skimmed off. Here is an image of the finished pallets with the soft jaws in the background. Using soft jaws in this manner meant the pallets could be firmly gripped in the shaped profile in the jaws without damaging the nib profile.

The finished pallets were fitted to the new silver steel arbor together with the locking boss. The clock was then tested using the original escape wheel. This appeared to function but it was sensitive to setup due to the damaged aspects of the original escape wheel.

The original escape wheel, while functional, had a number of bent teeth and two broken teeth. Two replacement teeth were fitted and filed to shape and the various bent teeth were reshaped. The original escape wheel was now much improved as a test wheel for the new pallets.

The next step was to run a trial version of the new escape wheel in aluminium. This was done in aluminium to save material cost and also to speed up manufacture. The aluminium wheel functioned very well but clearly was too soft for long term use. The added confidence gained from this interim wheel led to a new wheel being cut in brass. Once again, the 3D printed soft jaw method was used to skim the excess stock on the lower side of the machined workpiece. Here is the wheel after side one operations. The gripping excess stock needing to be removed can be seen. The wheel was then turned over and held in the soft jaws for the final cuts to be made to remove the excess stock as shown in the second image.



Here is the old wheel (left hand side) and the new wheel.

The only outstanding work on the pallets was to harden them. They were placed in a mild steel trough and covered with a paste of Boric Acid mixed with Meths. This mixture isolates the hot part from direct flame and reduces any scaling in the heating and plunging process. The complete block containing the pallets was heated to 800C and then oil plunged. Boiling water was used to free the pallets from the block. The pallets were left fully hard and cleaned to a bright finish.

Setting Up

The newly made parts were all assembled into the clock. Initially no driving weight was applied (from my earlier experiments it seemed that 20kg was sufficient drive).

The pallets were securely fastened to their associated boss and this in turn made tight to the new pallet arbor using the single grub screw.

The crutch was put loosely in place on the end of the arbor and the assembled arbor mounted in the new arbor bracket pivot. The two grub screw in the crutch mounting boss were left lose.

The pendulum was hung and shims put in place to stop any movement of the suspension spring top and bottom clamps. The pendulum now hung naturally in its central position.

The design of a 30 tooth escape wheel will require the distance between the pallet arbor pivot and the escape arbor pivot to be 1.414 times the escape wheel radius. This knowledge allowed the pivot arbor bracket to be roughly fixed in the vertical plane. (This equated to a 75mm measurement from the underside of the pendulum suspension bracket to the pallet arbor centre line). Without disturbing this vertical position, the bracket was then moved horizontally so that the suspension assembly hangs directly in line and covering the pallet arbor end. With these two settings fixed, the pallet arbor bracket can now be tightly locked in place and the two crutch grub screws likewise made fast.

A driving weight is added (~20kg) and the clock wound by a few barrel clicks. The escape wheel will now attempt to turn and in doing so will add pressure to one or other of the pallet nibs. If the static alignment of the pallet arbor bracket has been good then one or other of the images below will match how the escape wheel now sits relative to the nibs. These images show an earlier setting with the trial aluminium wheel in place.

Examples of the two possible wheel and pallet positions with the pendulum at rest in the centre

The pendulum is swung and checked that it swings symmetrically either side of the centre line of the pallet arbor shaft end. It is worth allowing a few minutes for the pendulum to settle down.

It is now important to watch and listen to the sound of the pendulum action relative to the pallets.

The sound of the clunk (aka the tick and the tock) should coincide with the arrival of the pendulum at its extreme points of swing. It should sound 'firm'.

The pallet action should now be watched. As each nib is released the escape wheel will rotate freely under the driving power applied from the winding weight. The rotational movement of the wheel once released and before being halted by the other nib, wants to be ideally less than a quarter of the gap between the teeth. This rotational distance is known as 'drop'. The nib should clear the tooth it has been released from then move a further rotational distance equivalent to the tooth width. This movement should be the same distance movement on both nibs. This is not always possible to perfectly achieve.

Now watch the action of each nib as it rubs on the curved section of the pallet face. Each nib in turn should engage and slide first of all up the nib face (short move) and then down the curve of the nib (long move). This action causes the escape wheel to momentarily stop and move slightly backwards to release the next pallet.

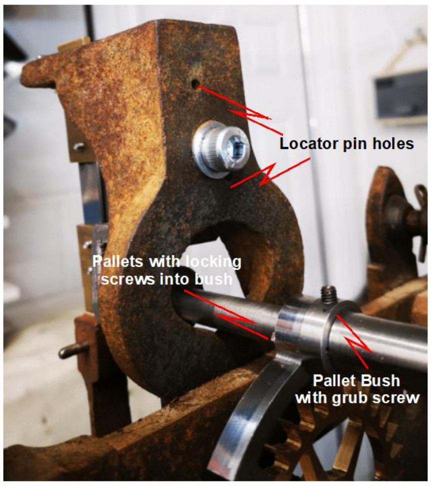
The aim is to get both nibs performing along a similar overall path length geometry on the nib faces. To repeat, this is a short inward movement and long slide off movement. If this is correct then the tick and the tock will coincide with pendulum extreme positions and the clock will sound balanced in the sound of the beat. To adjust this balance, it is necessary to release the grub screws on the crutch boss and slightly rotate its position on the pallet arbor relative to the pallets. Small changes will make a big difference so careful iterative changes are needed. This is best done looking at the escape wheel from the clock winding side. If the tooth is moving too deep into the pallet then stop the pendulum, loosen the crutch grub screws and while holding the crutch, turn the pallet arbor to reduce the depth of the nib into the tooth.

Depthing

If the pallet arbor mounting bracket screw is released and the pallet arbor mounting moved downwards (into the escape wheel teeth while maintaining its horizontal position) then this will reduce the 'drop' from release of a tooth to the wheel stopping, going backwards and then sliding off the nib face. Moving the pallet arbor too deep into the wheel will stop the wheel completely as the nibs will not have sufficient lift to clear the escape wheel teeth. Moving the pallet arbor outwards, that is disengaging too far, will lead to damage to the escape wheel as it will spin out of control and potentially abraded against the edges of the pallet nibs.

Too much 'drop' wastes driving energy. With careful adjustment the 'drop' can be set to barely the same width as the top of the tooth. Clearly this requires that the escape wheel, pallets, arbors and pivots are all perfect.

The frame of the clock adjacent to the pallet arbor mounting screw had two small holes. These are for pins to be fitted to make the positioning of the pallet arbor mounting bracket easily repeatable. Once a stable position is found for the bracket, the client understands that he must spot through these holes onto the bracket rear face and then drill and tap the two holes in the bracket. Two location pins with threaded ends can now be fitted into these holes to give long term positional repeatability of the bracket position.



<u>Timekeeping</u>

The pendulum length defines the timekeeping of the clock. The clock mechanism simply provides regular impulses to the pendulum to keep it swinging back and forth. Watching the crutch pin in the slot in the pendulum slot will show the pin twitch as this takes place. It is also possible with the light reflecting in the correct direction, to see a very slight tremor in the suspension spring but this should not be excessively so. If this is too noticeable it suggests that the pendulum spring needs to be of a thicker material.

To make the clock gain time the pendulum needs to be shortened.

To slow the clock the pendulum needs extending.

The clock in question is designed around a 1.25 seconds pendulum so theoretically the pendulum needs to be 1.553 metres long. The pendulum length and therefore the timing adjustment is done via the rating nut under the pendulum bob weight.

On a long pendulum clock, I recommend that the pendulum is adjusted to run slightly slow and a small tray be made and fitted to the pendulum rod well above the centre of gravity of the pendulum. Small weights added to this tray will speed the clock up and allow a fine tuning of the timekeeping accuracy to take place. Using this method allows changes to the timing to be made without dramatically changing the stability of the pendulum as it is running. I use combinations of pennies or large washers for large changes and then M4 nuts one at a time for small changes. If the washers or nuts are each looped on a short piece of cotton thread then they can be easily hooked on and off the weight tray with tweezers.

<u>Conclusion</u>

On receipt of the clock from the client I was concerned that I had underestimated the amount of work needed and that this would stretch me in delivering a working movement. The result has been very rewarding. I have learned how to draw an escape wheel and pallet from first principles, used a new hardening process, used 3D printed soft jaws for the first time and finally learned how to set up an anchor escapement. By having the combination of Fusion 360, my Tormach CNC milling machine and my Sindoh 3D printer this offers so many options for undertaking this type of work.