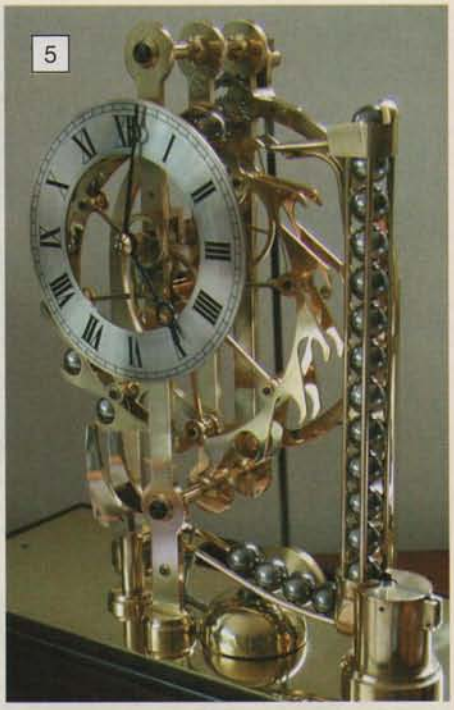
A FERRIS WHEEL CLOCK

Richard Stephen (left), designer of the unique Ferris Wheel clock described in this series, discusses the intricacies of preparing a CNC program with M.E. Assistant Editor Kelvin Barber.



The author has kindly agreed to assist constructors with any problems encountered. Correspondence will not be entertained, but brief telephone calls (01572-770416) or email messages to dickstephn@aol.com are welcome.

Richard Stephen
deals with the shaping of the nibs and assembly of the pallet before moving on to discuss the machining of the titanium escape wheel.

●*Part III continued from page 293 (M.E. 4168, 3 May 2002)*

Having been cut off, the two tungsten carbide nib blanks need to be silver-soldered to brass holders before they can be ground to shape. The brass holders are detailed in **fig 5**. A blank should be silver-soldered to the end of each holder as shown in fig 5.

There are two techniques for grinding the internal faces of the nibs. The method you choose will depend on the equipment you have available in your workshop. I have used both but since I bought my Wabeco mill and a rotary table, I now only use the second method.

Method 1

The first method, illustrated in **photo 6**, only requires a vertical slide fitted with a vice.

The first task is to prepare the guide for the brass holder. This is easily made from scraps of Perspex. The guide is dimensioned in **fig 6** and, as can be seen, the parts are glued together.

The best and easiest way to glue Perspex is to use chloroform if you can get hold of a small quantity. All that is necessary is to butt the two surfaces to be joined, then using an artist's medium sized paintbrush, apply a little chloroform to the joint. The chloroform will be drawn into the joint by capillary action. If the chloroform does not penetrate through the entire joint, the process should be repeated on the other edge. Clamp the join and leave for about 2 hours to harden. The result is properly known as a slovent welded joint. ***Please be sure only to use chloroform in a very well ventilated place, and keep it well out of reach of children***. If you cannot get hold of any chloroform use one of the proprietary Perspex adhesives.

Begin the work on the nibs using a copper lap charged with 20 micron diamond. Protect the lathe as previously described and, using a 90% paraffin plus 10% soluble oil lubricant in a hand sprayer, press the nib gently against the rotating lap. ***Please be aware of the fire hazards associated with the use of paraffin and take the necessary precautions.*** Don't run the lap too fast, if you use too high a speed you will have the lubricant everywhere. You will be able to judge that the lap is cutting if the lubricant turns black with tungsten carbide particles. When the lap ceases to cut, recharge it with diamond and continue.

You will need to grind the curve over the entire 6mm length of the blank. If the lap is well charged with diamond, the grinding will take very little time. Rough grind the second blank. Change the lap for one charged with 6 micron diamond and polish the surface. I find 6 micron diamond produces a perfectly adequate final surface but you can produce an even finer surface by finishing off with a 1 micron charged lap.

Remove the partly finished nibs from the brass holders by melting the silver-solder with a butane blowlamp. Allow the parts to cool and put them to one side.

Method 2

This is the method I now prefer for rough grinding the internal faces of the nibs. It involves the use of a small milling machine fitted with a rotary table. As mentioned above, I have a Wabeco mill and a rotary table, which is an ideal arrangement; **photo 7** illustrates the set-up.

Details of the Perspex grinding bath are given in **fig 7**. The brass nib holder is secured to the bath with a screw and its position adjusted to give the desired radius of curvature for the nib which, for the escapement we are making, is 11.87mm.

The bath is filled with water with a squirt of detergent and the face ground. When both nibs have been ground, the faces are lapped using a copper lap charged with 6 micron diamond, and finished with a 1 micron lap.

Remove the nibs and put to one side.

Pallet arms

The pallet arms are best made from 2.5mm gauge plate; however, if you have no gauge plate to hand, mild steel plate of the same thickness will be perfectly serviceable. For an escape wheel 25mm in diameter a 28 x 20mm piece will be required.

The simplest way of holding the steel blank is to soft-solder it to an off-cut of brass bar about 20mm in diameter and 20mm long. Grip the brass bar in a chuck and face the end, tin both the end of the brass bar and one side of the steel blank with

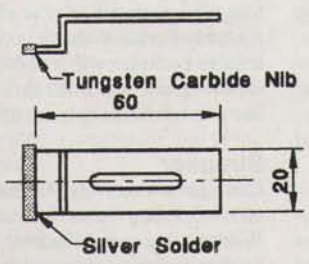


 Fig 5. Brass Holder for Nib Blank

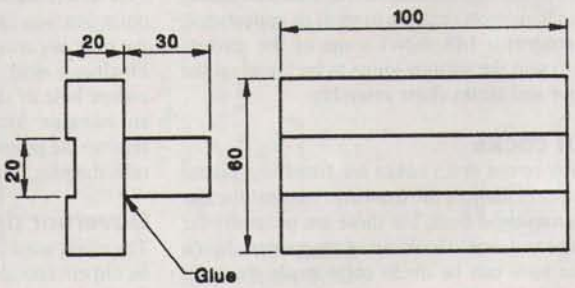
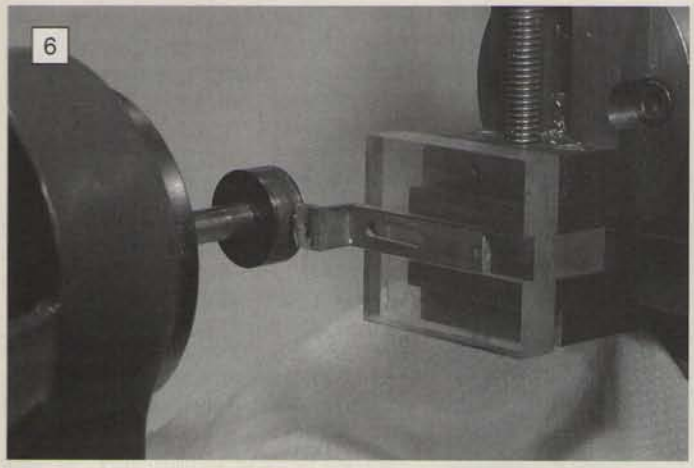


 Fig 6. Perspex Guide for Brass Holder



Method 1 for finishing the internal faces of the pallet nibs using a vertical slide and a lap mounted in the lathe headstock spindle.

Method 2 for finishing the pallet nibs using a milling machine and rotary table. Note the Perspex bath to contain the cutting fluid.

soft-solder and solder the two together so that the hole for the pallet arbor is situated centrally about 5mm from the long edge of the steel blank.

The diameter of the blank should now be reduced in the lathe until its *radius* is exactly equal to 0.95R. For our 25mm escape wheel, the diameter will need to be 23.75mm. Drill and ream to finish the 2mm hole for the pallet arbor. Unsolder the blank and, using wet and dry paper, clean off all the solder from the surface. Finish with some fine wet and dry.

Carefully wash and dry the blank and then blue the surface using a gentle flame to make marking out and sawing much easier. Using your drawing of the escapement as a guide, mark out the pallet arms on the steel blank. The thickness of the pallet arms at the ends should be no more than about 2mm. When the tungsten carbide nibs are silver-soldered in place this will leave about 4mm of the nibs protruding.

Silver soldering the nibs in place

The nibs should now be silver-soldered to the ends of the pallet arms. The only satisfactory way to silver-solder the nibs to the ends of the arms is to use the jig shown in **fig 8**. This will ensure that the internal faces you have so carefully ground and polished will lie precisely on the circumference of a circle centred at the pallet arbor.

The jig must be made from aluminium bronze as there is no other metal that does not readily silver-solder and withstands the high temperatures required for soldering. Plain aluminium is no use at all as it will not withstand the silver-soldering temperature. The radius of the jig is made 0.025mm less than the length of the pallet arms to ensure that the nibs butt snugly against the ends of the pallet arms.

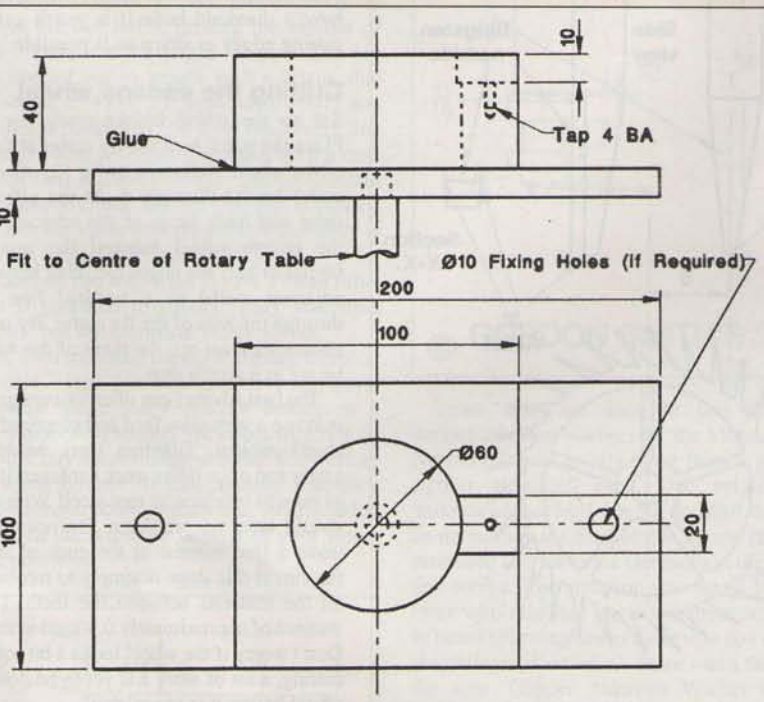
Before use, the jig should be gently heated with a blowtorch and then dipped into some old oil. Reheat the jig and allow the oil to burn off. This should coat the surface with a layer of carbon and make it even less likely for the silver-solder to stick to the surface.

Aluminium bronze is generally thought not to silver-solder. In fact, this is not true. It will silver-solder, though not well. The silver-solder will adhere if the metal is strongly heated for some time to evaporate the aluminium from the surface thus exposing the copper to which the silver-solder will adhere. The burnt oil deposits will help prevent the silver-solder from getting any grip at all, while making it easier to remove the pallets once they are silver-soldered.

Carefully clean the pallet arms, particularly the ends, using fine 1200 grade wet and dry paper. The ends of the arms should now be 'tinned' with silver-solder. After 'tinning' remove all silver-solder from the arms except at the ends where the nibs are to be attached. Leave just enough silver-solder on the ends to achieve a secure joint. Secure the pallet arms in the jig using a 2mm steel peg through the hole for the pallet arbor. Cover the ends of the pallet arms and both nibs with flux. Once the silver-solder melts, the surface tension of the liquid solder will pull the nib against the end of the arm. The ends of the nibs should stand just proud of the top of the pallet arms.

Lapping the front and back surfaces of the pallets flat

At this stage the pallets will look rather black and horrible and will need cleaning and lapping flat. The presence of the tungsten carbide nibs means that you cannot use a file. The quickest way to clean up the pallets is to use a flat diamond hone. I made my own using a piece of 10 micron ▶



© Fig 7. Perspex Grinding Bath

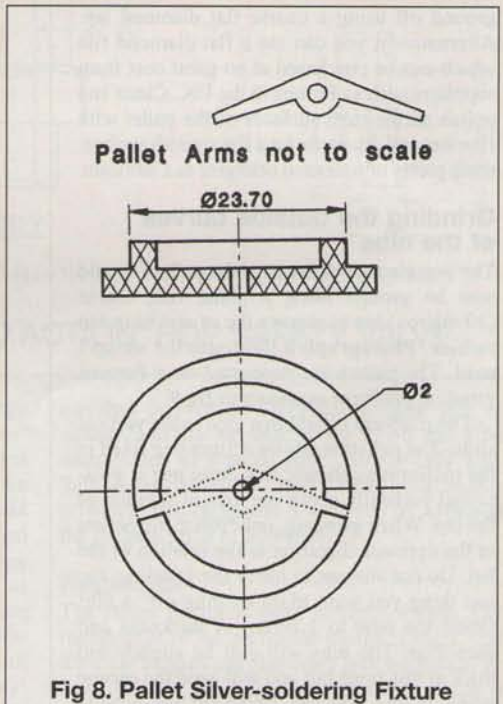


Fig 8. Pallet Silver-soldering Fixture (Aluminium bronze) ©

diamond lap stuck to a piece of 6mm aluminium alloy plate with Superglue. A piece 150 x 25mm cost me £6 from Marcon Diamond Products Ltd.

If you have no diamond hone, an alternative way to lap the front and back of the pallets is to use carborundum powder on a flat cast iron surface. You will need a piece of cast iron about 120 x 60mm whose surface is absolute flat and smooth. Start with 200 grit carborundum powder. Put about one teaspoonful in the center of the plate, add a little water and a couple of drops of washing-up liquid and smear the mixture over the plate. Using firm pressure rub the surface of the pallet against the plate. When you have ground away all scale, silver-solder and grot from the surface turn the pallet over and do the other side. You may need to use a bit more carborundum. You will be surprised how easily the pallets clean up and the carborundum laps the tungsten carbide.

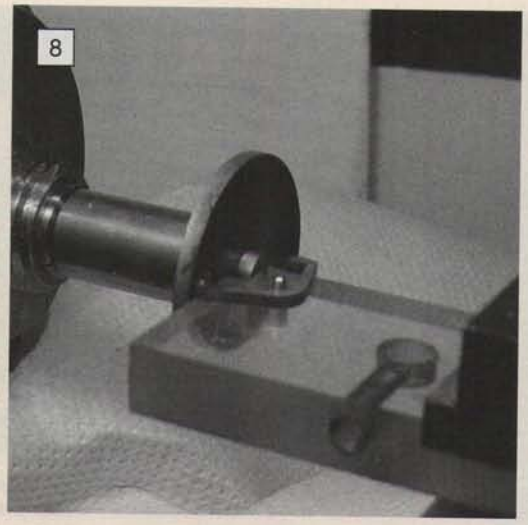
The resulting surface will not look shiny but will have a dull grey appearance. Wash the plate carefully to remove all the 200 grit carborundum and repeat using 600 grit, finishing with 1200 grit. Finally, polish the surfaces with 1200 wet and dry paper. Using needle files, clean off the excess silver-solder from the internal surfaces of the nibs and the pallet arms. There is no danger of scratching the polished surfaces of the nibs, you are more likely to remove the teeth from the files! You will find the silver-solder comes off reasonably easily. Any silver-solder which you cannot get off with a file can be removed with a fine sharp scraper followed by fine wet and dry paper.

The pallet arms can now be filed to their final thickness. Any excess tungsten carbide will have to be ground off. The best way to proceed is to file the steel arms to their final thickness up to the nibs. The excess tungsten carbide can then be sawn off using the diamond saw, or if only a small amount is to be removed, it can be ground off using a coarse flat diamond lap. Alternatively, you can use a flat diamond file which can be purchased at no great cost from suppliers such as Proops in the UK. Clean and polish all the steel surfaces of the pallet with fine wet and dry paper on a flat smooth surface, using plenty of water and detergent as a lubricant.

Grinding the outside curves of the nibs

The outside curved faces of the pallets should now be ground using a plain, flat, coarse (20 micron) lap to remove the excess tungsten carbide. **Photograph 8** illustrates the set-up I used. The pallets are supported on a Perspex grinding platform as shown in **fig 9**.

The platform is held in a vice in the vertical slide. The pallets rotate on a 2mm peg fixed in the platform as shown; this 2mm peg is positioned vertically above the axis of rotation of the lap. When grinding, only rotate the pallets in the opposite direction to the rotation of the lap. Do not attempt to hurry the grinding, the last thing you want to do is 'ping off' a nib! Grind the nibs to 1.20mm in thickness and then stop. The nibs will still be slightly too thick at this stage but you will need the escape wheel before you can finish off the outside faces of the pallet.



Lapping the outside curved faces of the pallet nibs using a face lap mounted in the lathe spindle. Note the paper towels to protect the lathe bed.

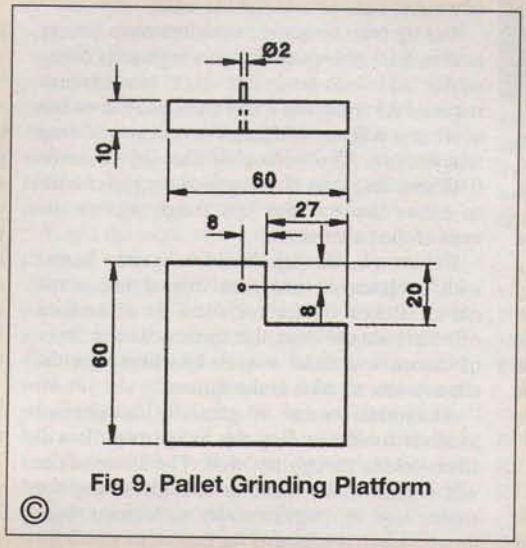


Fig 9. Pallet Grinding Platform

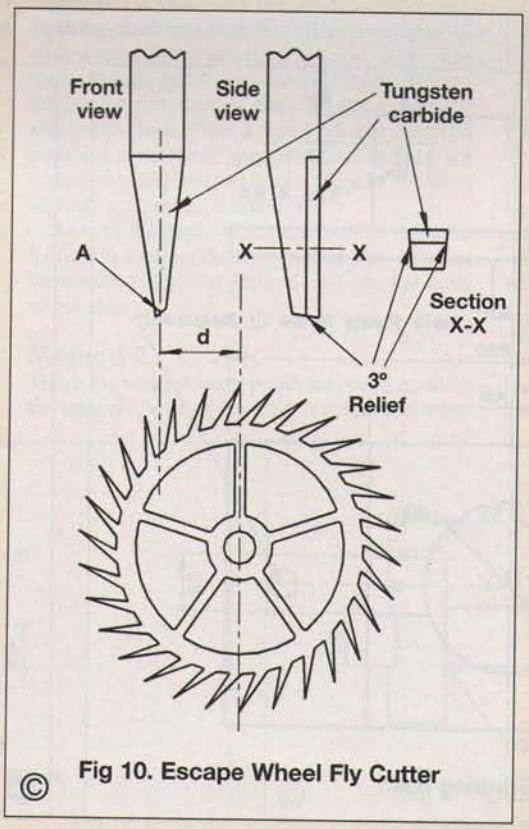


Fig 10. Escape Wheel Fly Cutter

Escape wheel

A start can now be made on the escape wheel. As mentioned earlier, I would advise making the wheel out of titanium. The only problem you are likely to encounter is obtaining a small piece of the material. Titanium sheet is extensively used in the aircraft industry, particularly in military aircraft! You will need a piece 27mm square and 1mm thick as well as two pieces of engraving brass sheet of similar dimensions.

I have a Schaublin 70 lathe in my workshop on which I do my wheel cutting. The wheel blanks are initially drilled 4.0mm centrally, and fixed onto a true mandrel with the titanium sandwiched between the two brass blanks which support the titanium during cutting. Turn the blanks down until they are 25.1mm in diameter; the actual diameter is not critical provided it is slightly oversize. This is quite intentional as once the wheel is cut and crossed out it will be reduced in diameter until it precisely matches the required size for the pallets.

Carbide tipped fly cutter

To cut the titanium wheel you will need a tungsten carbide tipped fly cutter. You could try using high speed steel for the fly cutter, it *may* be okay but if it becomes blunt during use it will be difficult to re-sharpen and re-set the cutter. The dimensions and construction of the carbide tipped fly cutter I used are shown in **fig 10**.

You will need to use the drawing of the escapement to measure the various angles when grinding the cutter. Two or three degrees of relief are all that is required for tungsten carbide cutters. To grind the fly cutter you will either have to use a green grit (silicon carbide) grinding wheel, or a diamond wheel. I ground my fly cutter on an old diamond wheel which I picked up in a second hand tool shop. If you have a diamond hone it is worth getting the cutting edges as sharp as is possible.

Cutting the escape wheel

Set up the wheel blanks ready for cutting. Place the point **A** of the fly cutter at the centre of the wheel. Referring to fig 10, offset the fly cutter by the distance **d**. At the offset **d**, the front and back faces of the adjacent teeth of the escape wheel subtend the same angle (equal to half the angle included between two adjacent teeth) to a vertical line passing through the axis of the fly cutter. By using this geometrical set-up, the teeth of the wheel can be cut at a single pass.

The best advice I can offer for cutting titanium is to use a very slow feed and plenty of a water-based coolant. Titanium work hardens very easily and once it has work hardened it is about as easy to machine as tool steel! With care you should have no problems. Do not attempt to leave a fine witness at the ends of the teeth; the aim at this stage is simply to remove nearly all the material between the teeth. I leave a witness of approximately 0.50mm at this stage. Don't worry if the wheel looks a bit rough after cutting, a lot of work has yet to be done on the wheel before it is completed!

●*To be continued*