# A FERRIS WHEEL CLOCK

**Richard Stephen**
deals with the wheels and pinions and describes the construction of the Ferris wheel itself.

●*Part V*

*continued from page 502 (M.E. 4172, 28 June 2002)*

11

***Close scrutiny of the wheels and pinions assembled in the Author's clock reveals the very fine finish obtained on all the individual parts.***

The materials required for the wheels and pinions for this clock, and their details are shown in **tables 1 and 2** and in **fig 15**.

Cutting the wheels should present few problems. It is worth cutting at least two spares of each of the wheels; it is as easy to cut four wheels at a time as it is to cut one. I have learned to my cost that it is quite easy to ruin a wheel when crossing out; having a spare to hand at such a time is very handy. Even if you do not use the spares, it is as well to store them away; you may be glad of them at a later date. The dimensions of the centre wheel pinions are also given in fig 15.

It is not necessary to use steel for these pinions, brass bar is quite adequate. The centre wheel pinions can be cut satisfactorily with a wheel cutter. For both centre wheel pinions the hole for the arbor is 2.5mm diameter. A tip when cutting the smaller pinion wheels is to make a trial blank from brass rod. Cut two trial teeth, remove the blank, and check using a powerful glass that the tooth cut is truly radial. If not, adjust the position of the cutter and repeat until the tooth cut is truly radial.

Replace the brass blank with the steel blank and cut the pinion but don't cut the teeth in a single pass. The initial cut should remove about 90% of the material and the final cut the remaining 10%. You will find that free-cutting mild steel cuts much more easily than any other type, and the finish is much better. Use the slowest feed speed and plenty of water-based cutting lubricant.

If you cut the pinions on a lathe, drill the 1.6mm hole for the arbor before you remove them from the chuck.

## Case hardening the pinions

Before hardening the pinions, true up and smooth the ends. The safest way to do this is to use the side of a carborundum cutting disc in a Dremel mini-drill. Hold the pinion in a collet in the lathe and grind the faces true. Now make a mandrel from a 60mm length of 3mm dia. steel rod. Using a file, taper the end so that it fits tightly into the hole in the pinion. Grip the mandrel in the chuck of a hand drill or a battery powered cordless electric drill — *don't use a mains powered drill.* Check that the pinion rotates truly. Heat the pinion with a blowtorch while rotating it at the same time.

When it is hot (not red — read the instructions!) dip it into the case hardening powder and return it to the flame. Repeat this process until you have built up a good covering on the pinion. Now heat the pinion up to red heat and maintain it at temperature for at least a minute, rotating it in the flame all the time to ensure even heating. Quench the *still rotating* pinion in cold water. Quenching the pinion while rotating will prevent any distortion from occurring.

With the wheels cut and the pinions hardened, the teeth on both the pinions and wheels should be polished. Polishing the teeth significantly reduces the engaging friction in the train.

## Making the polishing hob

To make a hob you will need a 70mm length of 25mm square boxwood or any other close grained hardwood. Grip the block of wood in a 4-jaw chuck in the lathe and turn a cylinder approximately 20mm in diameter. Drill a 6mm hole through the cylinder and cut it into two pieces, each about 30mm long. This gives enough material to make two hobs, one for brass wheels and one for hardened steel pinions. Make the mandrel shown in **fig 14** and attach one of the hob blanks.

Screw-cutting wood using conventional methods is a problem because, being rather brittle, the wood tends to break up. I cut all my wheels on the lathe using a milling spindle fixed to a vertical slide. The easiest way to cut a clean thread on the hob is to use the milling spindle and the cutter you used to cut the wheel you need to polish.

Fix the vertical slide so that the axis of the milling spindle is parallel to the bed of the lathe. Using the spindle, cut a thread in the hob blank with the same pitch as that of the wheel you want to polish. For this clock you will need 4 hobs, two each for the 0.30 and 0.40 module wheels and pinions. The suitable pitches for the hob threads are 1mm (0.30 module) and 1.25mm (0.40 module).

## Polishing the teeth

Grip the hob on the mandrel in a collet or 3-jaw chuck and charge the hob with a polishing compound. If the wheel being polished is made of brass, the polishing compound should be a non-embedding abrasive. Suitable non-embedding abrasives include any of the domestic metal polishes, e.g. Brasso.

For hardened pinions, 1200 grade carborundum powder is the most suitable. When using carborundum powder, care must be taken to ensure that the carborundum remains on the hob and does not scatter all over the lathe to do untold subsequent damage! To overcome this difficulty mix a small quantity of the carborundum powder in a jar with some thick cutting fluid, e.g. Dormer Supacut, which has the consistency of thin honey and is about as sticky! The mixture sticks very well to the hob, as well as anything else! The lathe bed and compound slide should be protected with paper

**Table 1 - Wheels & Pinions: Materials**

| | |
|---|---|
| Ferris Wheels: | 1.2mm brass sheet (CZ180) or 1.5mm brass sheet (CZ120) |
| Centre Pinion: | 12mm brass rod (CZ121) |
| Centre Wheel: | 1.2mm brass sheet (CZ120) |
| Intermediate Wheel: | 1.2mm brass sheet (CZ120) |
| Pinions: | 6mm mild steel rod (EN1A) |

The drawing of the Brass Foot on page 501 (*M.E.* 4172, 28 June 2002) should have called for one foot with a 3.5mm groove, not 3mm as indicated. We regret any inconvenience this may have caused.

**Table 2 - Wheels & Pinions: Details**

| Description | Number of teeth | Module | PCD (mm) | Full dia. (mm) |
|---|---|---|---|---|
| Drive Wheels (2 off) | 100 | 0.40 | 40.0 | 41.10 |
| Centre Pinion (2 off) | 25 | 0.40 | 10.0 | 11.10 |
| Centre Wheel | 144 | 0.30 | 43.2 | 44.03 |
| Intermediate Pinion | 12 | 0.30 | 3.6 | 4.08 |
| Intermediate Wheel | 120 | 0.30 | 36.0 | 36.83 |
| Escape Pinion | 12 | 0.30 | 3.6 | 4.08 |

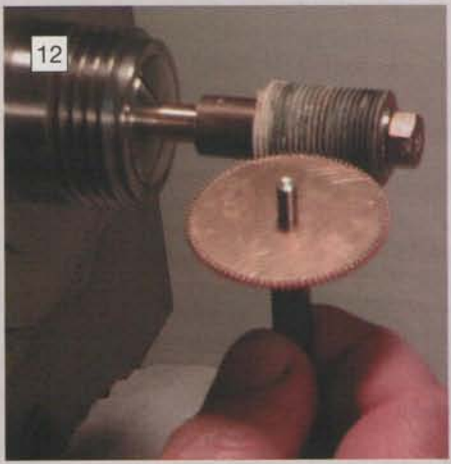
kitchen towels to ensure that the abrasive does not go where it is not welcome!

The wheel, free to rotate on a *hand held* arbor is engaged in the thread, as shown in **photo 12**, with the plane of the wheel aligned with the axis of the rotating hob. To avoid any possibility of distorting the wheel, polish the teeth before you cross it out. As the hob rotates, it forces the wheel to rotate as well, polishing one flank of each tooth in the process. The wheel is turned over to polish the other flank.

## Crossing out the wheels

Once you have finished polishing the teeth of the wheels you should cross out all the wheels. The dimensions for the crossings for all the wheels are shown in **fig 15**. The spokes are all shown as being slightly tapered which is a personal preference of mine. How you decide to finish the spokes is your choice.

I leave all the internal corners rounded with a radius of 1mm just as they are after crossing out on the CNC milling machine. With the crossing out completed, the wheels should be finished off on 1200 grade wet and dry paper in a bath of water to which has been added a squirt of washing up liquid. This prevents the abrasive paper from clogging and improves the final finish. The wheels will be brought to a final high polish once the clock is completed.




*The teeth of the wheels and pinions are polished by rotation against a boxwood hob loaded with a suitable abrasive. For this operation, the wheels and pinions are supported on a hand held arbor.*

The dimensions of the collets for the wheels are also shown in fig 15. These look best made in steel and polished. Fix the wheels to their collets using Loctite Screwlock. This will adequately secure the wheels to the collets and enable you to test the clock, but still allows them to be removed relatively easily for final polishing. Once the clock is finished the wheels can be permanently secured to the collets using Loctite High Strength Retainer.

## Ferris wheel

The details of the Ferris or ball wheel are shown in **fig 16**. The wheel is made from 1.2mm CZ108 brass sheet rather than CZ120 (engraving brass). The reason for using CZ108 is that it is significantly stiffer than engraving brass, thus allowing the wheel to be a little more

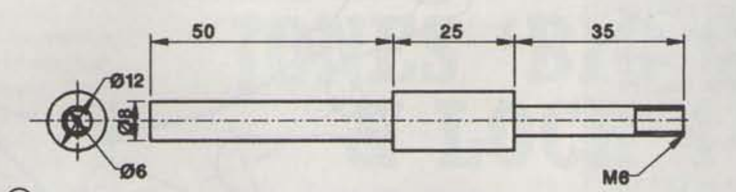



**Fig 14 - Polishing Mandrel**

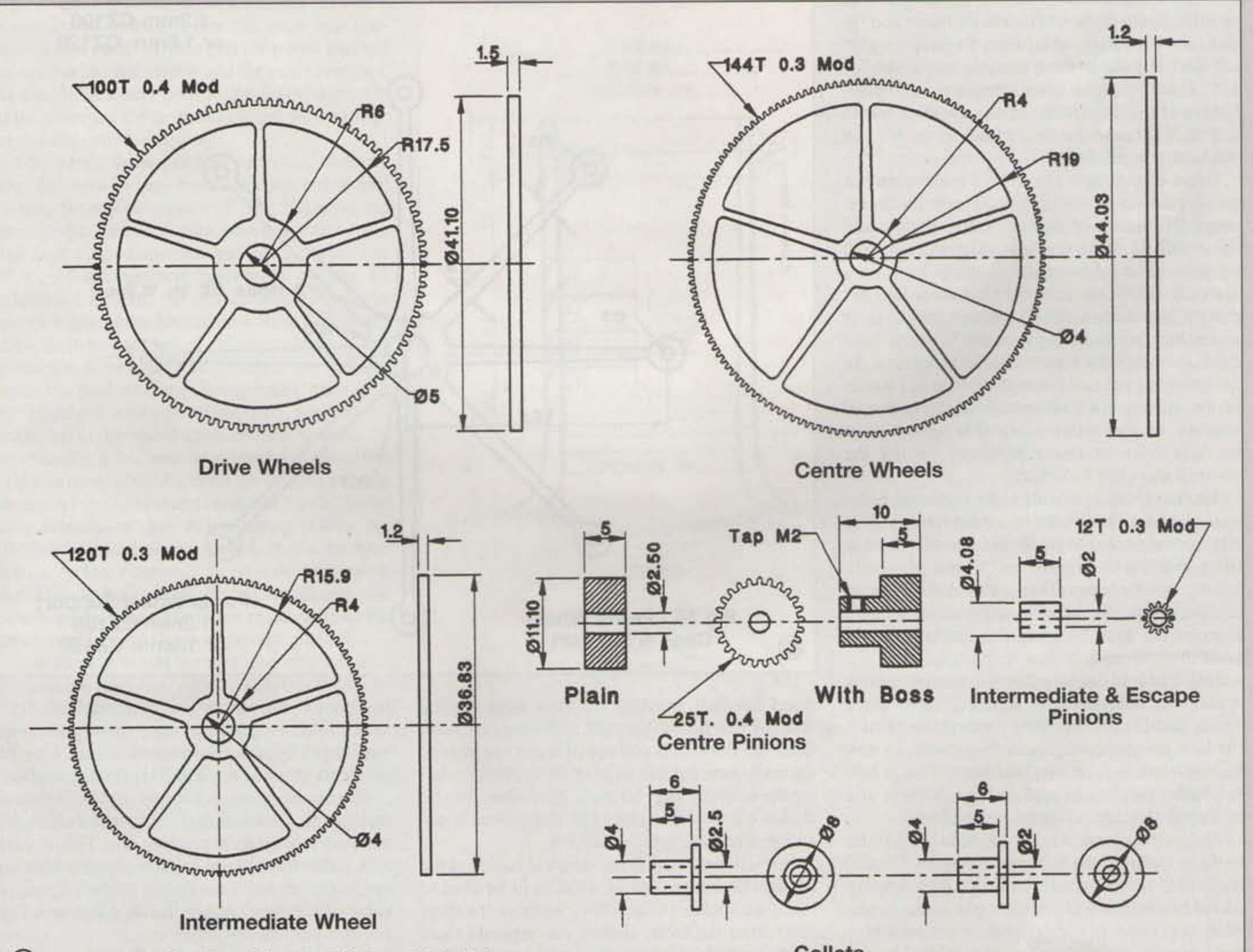



**Fig 15 - Wheels, Pinions & Collets**

delicate. As a result, CZ108 is rather more difficult to cut than engraving brass. If you prefer an easy life and don't want to use CZ108, preferring instead to use engraving brass, I suggest you use 1.5mm thick material.

The Ferris wheel must be accurately made. All the ball slots must be identical and spaced exactly 22.5deg. apart around the circumference of the wheel. If the slots are not all identical and eqi-spaced, the balls will not drop out of the wheel at the same angular positions. When they drop off the wheel, the balls have to fall exactly between two electrical contacts, closing a circuit and switching on the drive that raises the balls. I cut my wheel on the Wabeco CNC mill which, although it took about a full day to completely cut out the three sections, made an excellent job of it.

Exactly how you will tackle the wheel depends on the equipment available. The parts could be made entirely by hand, which will require some very careful marking out and fitting. The job will be considerably easier if a milling machine with a good rotary table is available.

## Making the Ferris wheel

A piece of 1.2mm CZ108 (or 1.5mm CZ120) brass sheet 450 x 150mm is required for the Ferris wheel. Start by roughing out three discs to 170mm diameter. Cut a disc of 12mm plywood or MDF board about 180mm in diameter and fix this onto the rotary table. Take all three roughly cut discs and screw them securely to the wooden disc. Ensure that the discs are centred and positioning the fixing holes in the areas of waste material. Do not stint the number of screws you use to secure the discs.

Begin by cutting a 12mm hole in the centre of the three discs. If you can accurately locate the centre of rotation of the rotary table, you could use a drill to make the hole. Alternatively, and possibly more accurately, mill the hole using a slot drill. It will not matter at all if the hole is not exactly 12mm diameter, all you will have to do is make the arbor to fit the resultant hole you have made. Now set the rotary table at 0 degrees. As accurately as you can, position the axis of rotation of the milling machine spindle at the centre of rotation of the rotary table. For convenience we will refer to this position as having the co-ordinates (X = 0, Y = 0).

The next task is to drill eight 3mm dia. holes spaced 45deg. apart on the circumference of a circle having a radius of 60mm. The first hole is to be drilled at the co-ordinates (X = 0, Y = +60).

Next drill sixteen 12mm dia. holes spaced 22.5deg. apart on the circumference of a circle having a radius of 71.5mm. The first hole should be at the co-ordinates (X = 0, Y = 71.5).

Drilling large diameter holes in thin material is sometimes difficult. My technique is to use a series of drills of increasing diameter and finish the hole using a boring head. The discs can now be machined to their final diameter. This is best done taking light cuts against the side teeth of a milling cutter, preferably a sharp end mill.

Machine the track way for the balls next. Refer to the drawing of the ball cage in fig 16. Careful study of the drawing will reveal that the track way of the slot immediately to the right of the uppermost slot (in the 12 o'clock position) is parallel to the X-axis of the milling machine table. Using a sharp slot drill, machine the track ways starting with the first hole to the right of the topmost hole. Once the slot drill is positioned to cut one edge of the track way, cut this edge of all the slots, rotating the table 22.5deg. for each. Reposition the slot drill to cut the other edge. The sharp corners can be removed later using a fine file.

You will now have three identical copies of the Ferris wheel cage, one of which will be used to make the spokes of the wheel. Remove the three discs from the table. Before you separate them mark each one so that when you have finished making the wheel they can be assembled in the same relative positions as when they were machined. By this means, you should have no problems aligning the wheel on final assembly.

If you have no access to a CNC milling machine, the spokes of the Ferris wheel are probably best cut out using a piercing saw Finish them with a fine file and wet and dry paper. A piercing saw is also probably the easiest way to cut out the sides of the cage. Again, finish off with a fine file and wet and dry paper.

● *To be continued.*

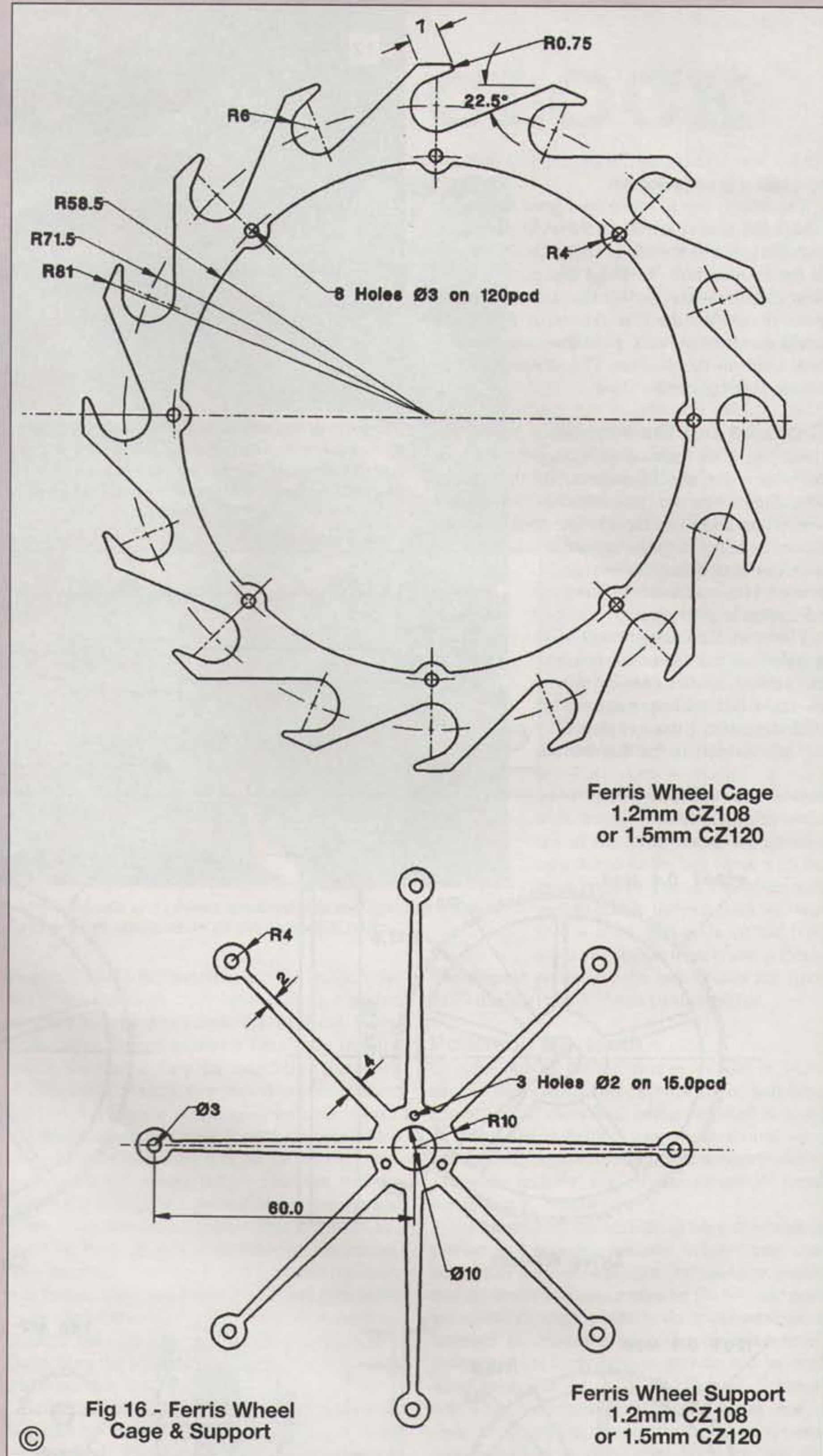



Fig 16 - Ferris Wheel Cage & Support