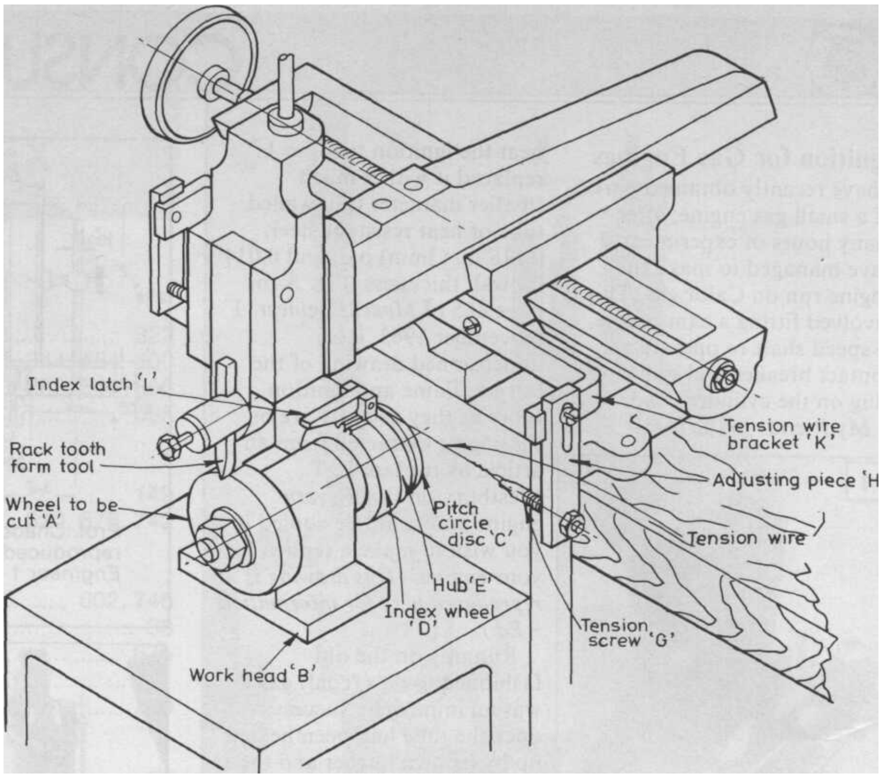
Having built four locomotives - *Rob Roy* and *Jubilee* in 3 1/2 in. gauge and the two Kettering Furnaces No. 3 in 7 1/4 in. gauge - I felt that a change would be as good as a rest and looked for a different type of project. Initially a clock was favoured and several designs examined and discarded mainly because of the woodworking involved. I am one of those persons who picks up a nail to hammer into a piece of wood only to find that the timber has split.

Thoughts then turned to a traction engine, machines which have held a fascination for me since early childhood; indeed I had once gone as far as building the boiler for an Allchin *'Royal Chester'.* However, I had disposed of the castings some time ago as I felt that a lot of the work was too fiddly for my deteriorating eyesight.

After examining a number of general arrangements the Fowler R3 two cylinder compound, three speed engine offered by Messrs Plastow was decided upon. Drawings for this engine are offered in both of its incarnations, as a Road Locomotive and Showman's Engine. Whilst being a necessarily complex design this was of no matter as I was looking for an 8-10 year project.



This is the drawing which was published as Fig. 1 of the original article by Base *Circle,* see text for an explanation.

SHAPER-CUT

Coincidentally Mark, the young man who had assisted me with the first steaming of the No. 3's asked to participate and build the Road Locomotive version as I had decided to tackle the Showman's Engine. This is proving to be a most satisfactory arrangement as Mark has some very useful skills and has undertaken to obtain materials, it will be very useful to have an extra pair of hands at boiler making time.

Examination of drawings obtained from Messrs. Plastow indicated that a number of gears would need to be produced in a range from 13T to 96T in 10 DP plus bevel gears and pinions and thought was given as to how these could be made. One of my most used workshop tools is an almost complete set of *'Model Engineer's'* and recourse was had through the use of my self compiled master index to see how past contributors had tackled the problem.

In *Model Engineer,* 14 September 1950 an article by *Base Circle* describes a simple and elegant method of coupling a gear blank to a shaper longitudinal feed and using a simple tool to generate teeth. As *Base Circle* points out this produces teeth of correct involute form whatever the number being cut. Being the possessor of a small 'Perfecto' motorised shaper this appeared to be the way to go, especially as my old WWI. Cater and Hakes No. 2 horizontalmillingmachinehasinsufficient capacity to handle the larger gears using involute gear cutters.

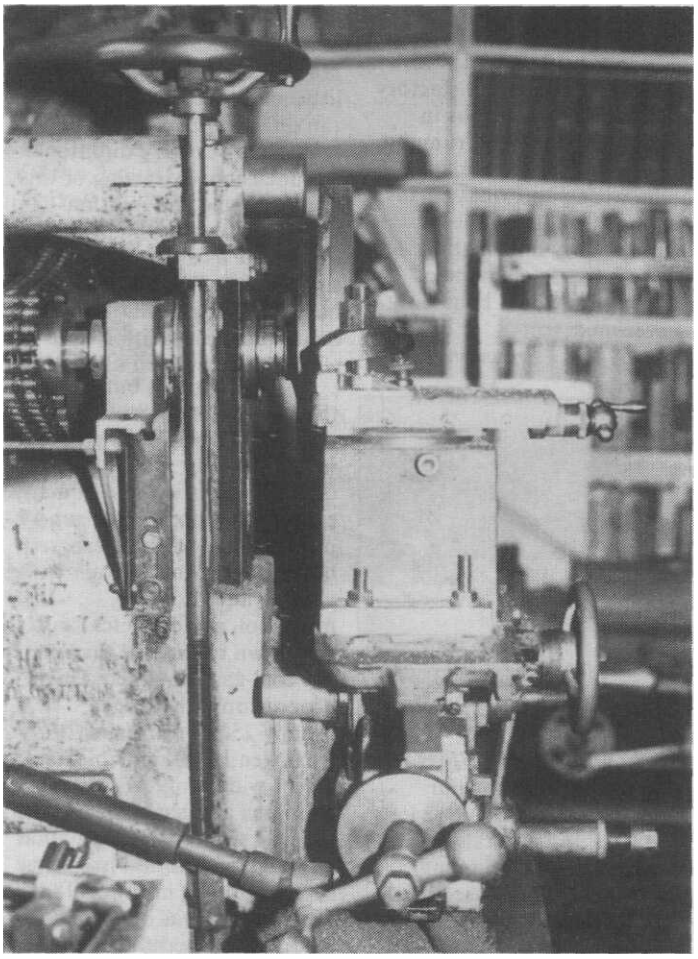


Fig. 1: ***Machining the blank for the 96 tooth gear on the milting machine. Note the use of adaptors for the Myford faceplate and topslide holder.***

Having decided upon a method, the problem of producing the 96T blank had to be solved. This blank is 9.8 in: dia. and I proposed to machine it from a manhole cover casting. This, however was significantly larger than the 10 in. that my Myford Super 7 lathe will swing in the gap.

Another look at the milling machine showed it to be possible to machine a plug mandrel for the spindle to accept Myford chucks and face plates, so this was turned and Mark obtained a suitable casting upon which to mount the lathe topslide. Fig. 1 & 2 show the arrangement. Surprisingly for such a lash-up the rate of metal removal and rigidity is quite good, and it was certainly very pleasant to have the power cross feed available.

A minor, but important detail was to dowel the casting, prior to machining the second face, to the faceplate for second operations, especially that of trepanning to an internal diameter after gearcutting.

Incidentally, I am a firm believer in production planning and a written procedure for such operations. This very largely prevents the situation arising whereby you have removed metal now required for location or measurement. In this instance I attempted to foresee operations as a complete event to enable subsequent work such as keyway cutting to be carried out with automatic location upon a fixture. Thought had been given along these lines as to how this relatively large casting could be presented to the shaper tool, and indexed, the final arrangement is shown in Fig. 3.

GEARS

Australian reader C. Bamford decided to build traction engines. He chose to make all the spur and bevel gears first, using milling machine and shaper *Part 1*

Method Adopted

The basis is a large angle plate machined to slide vertically upon that portion of the shaper that normally carries the work holding table. The angle plate is accurately machined on all four faces and the longer face has so far proven to be the only part not possible to machine within my own workshop.

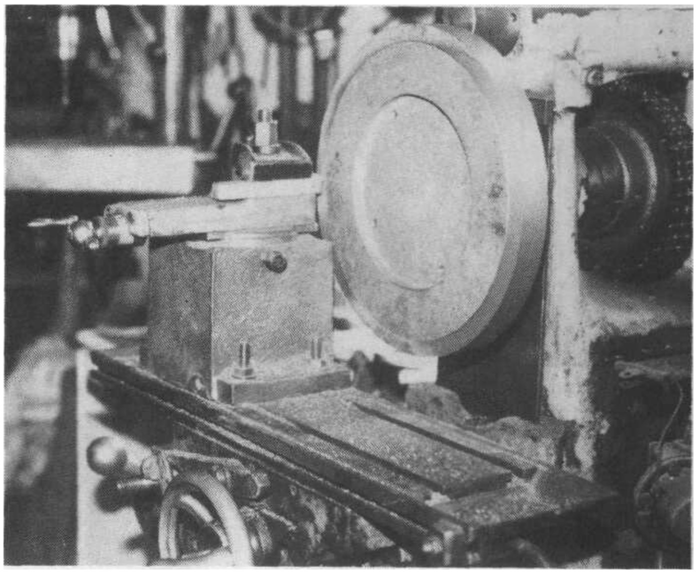
To raise the blank to machining height two further castings were obtained, one to carry a spindle which secures the blank at one end and the indexing arrangement at the other. This casting was made to handle the remainder of the castings and thus a supplementary raising block was required. Fig. 3 also shows the connecting wire to the pitch circle disc, the diameter of which is blank pcd minus wire diameter, in this case 0.050 inch. The figure shows the final arrangement arrived at after some dearly bought experience, for whilst *Base Circles* method works, his description is devoid of a number of pitfalls into which I fell. I suspect that he was cutting much smaller gears than I was undertaking.

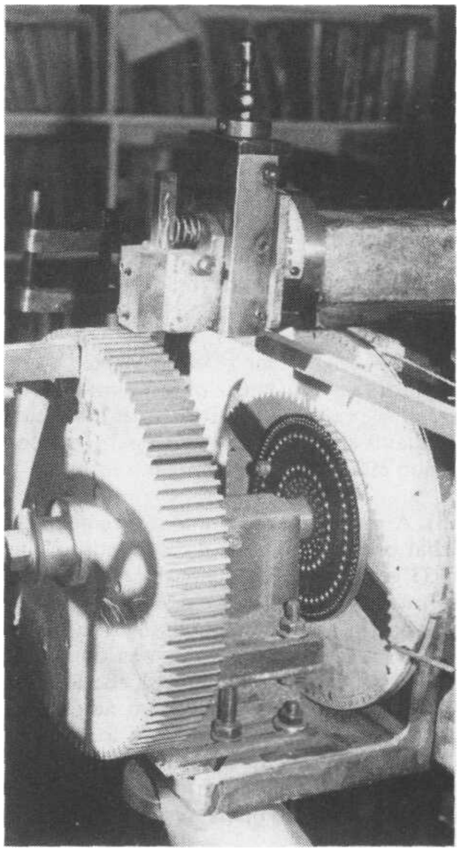
Fig. 1 of the original article is reproduced; it will be seen that the shaper table is connected to the pitch circle disc by a wire tensioned between a "U" shaped metal bar of substantial section affixed to the longitudinally moving portion of the machine.

Experience has proven that this wire *must* be very firmly anchored to the P.C. Disc and be level; I used a line level.

Right, Fig. 2: *Machining the second face of the 96t. blank,*

Below, Fig. 3: *Cutting the teeth in the 96t. gear, the final arrangement.*



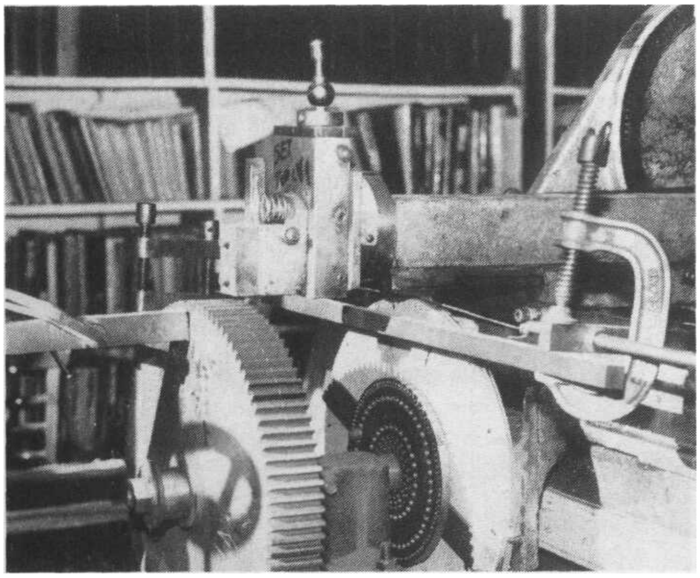


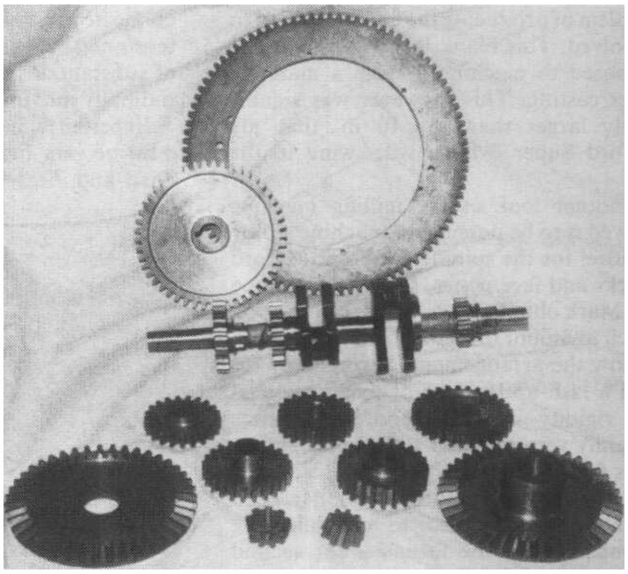
Initially indexing was done by an outer ring of holes in the metal disc, which was indexed using the Myford dividing head. A pin locates in a hole in the P.C. disc. When the nut at the rear is loosened, the blank is rotated one hold and the nut tightened. The tool shape of 29 deg. included was ground upon the Quorn to dimensions obtained from Machinery's Handbook for a 10 D.P. rack.

Following *Base Circles* suggestion a roughing and finishing cut was proposed and cutting commenced. Immediately, everything that was possible to shake loose did so, the crashing and banging was horrendous and the amount of rocking at the blank amazing.

A halt was called to tighten shaper gibs and packing placed under the angle plate and between it and the bench, and a bar fastened to the milling machine table, (fortuitously conveniently placed), to brace the blank. It was also found necessary to shim the clapper box to eliminate endwise movement and to pack the tool in the slot, I used a number drill for this. Finally a small spring between clapper box and slide was needed to return the box vertically after the return stroke. A grub screw replaced a gib screw in the vertical slide to enable the slide to be firmly locked. Operations recommenced and eventually by elimination, things settled down.

By fortunate chance I had the use of a gear tooth vernier and this enable me to maintain a check upon tooth form. I was amazed to find significant variation between adjacent teeth. Following investigation it was discovered that slight variations in the index hole spacing, probably caused by drill wander, was being multiplied at the blank periphery and so the method shown in Fig. 3 was substituted, 96 holes being drilled in the perimeter of the





P.C. disc and a bar fastened to the index plate, with the pin for indexing; this system proved adequate.

None the less, when the second, finishing, cut commenced it was immediately clear that the required result was not being obtained and attention focussed upon the tool. Investigation showed that the rack form tool tip was too broad and gradual slimming on an *ad hoc* basis eventually produced a suitable tool. Rightly or wrongly, I had calculated that to produce a rack the flattened tip must be 0.115 in. wide; however, in final form this reduced to 0.095 in. As two blanks were being machined together this meant that two further blanks had to be produced to replace the experimental pair, and this was done.

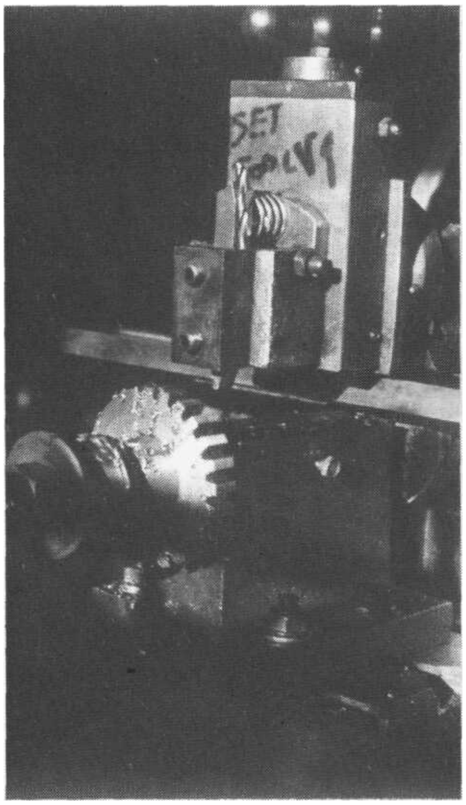
In case anyone is wondering why machining commenced with the most difficult operation it was because we wished to complete the gears before ordering castings from U.K. In the event of failure we had the option of availing ourselves of Messrs. Plastow's gear cutting service.

To shorten what could become a tedious story, by the time the 13T gear was to be cut I had developed a method that was giving very satisfactory results, in fact I was almost sorry to stop, *Base Circle* states that it is an 'interesting' operation to watch, I found it fascinating.

Operational Hints

For anyone considering using the method a few pointers may be of use:-

1). As mentioned, everything in the set-up must be as firm as possible. Obviously I was overloading the machine with the 96 tooth blank, but even so a calamity ensued on a smaller blank when the anchor screw on the P.C. Disc loosened. I found three cuts per tooth gave best results for a depth of 0.20 in. (clearance at root of 0.015 in.), a roughing cut all around of 0.015 in. and *two* at the final 0.20 in. depth. The first finishing cut removed a majority of the metal, and the second a much smaller amount which improves the finish and



compensates for vertical movement of the blank under tool forces.

2). As the number of teeth reduce there appears to be a change of form but measurement proves that thickness at the p.c.d. remains constant. Maintaining this dimenstion effectively controls tooth form.

3). A problem not entirely overcome was that of measuring the tooth depth on the 13T gear due to the angularity of the teeth. However, by visual checking with the mating gear and maintaining the p.c.d. width a satisfactory result was obtained. Incidentally, by juggling with the tension wire anchors it is possible to adjust the relationship between tool and tooth gap. Experience taught that the best results were obtained by ensuring that the relationship between blank and tool remained undisturbed.

Top left. Fig. 4: ***The final arrangement and finishing cut on the 96t. gear,***
Above, Fig. 5: ***Fourteen gears, one set! Bevel gears and pinions in the foreground.***
Left, Fig. 6: ***Roughing the 21t. gear. Note reminder to set tool vertical. No. drill packing on the toot and the spring to return the clapper box.***

4). The P.C. disc diameter *must* be accurate. I got some very funny shaped teeth when I forgot to subtract the tension wire diameter. I also found that no radius was required at the tool tip other than that required by normal tool grinding practice as the rotation of the blank formed an appropriate radius automatically. Tool wear was surprisingly little even when mild steel was being cut. The tool *must* be vertical.

Fig. 5 shows the finished gears, together with the crankshaft and bevel gears and pinions. The method of producing these will be described next time, as will the method of producing the various keyways. Fig. 6 is a close view of the 2IT gears during the roughing cut whilst Fig. 7 shows the final cuts to the 13T gears. Apparent in this view is the limited clearance for the tool at the 1.5 in. dia. required and the 2BA bolt used to lock the spindle when indexing.

In summary this has proven to be a thoroughly practical method provided a shaper is available and a modicum of care exercised. Admittedly one has to stay alert for problems. I would suggest, in order to arrive at correct tool shape a little experimentation be undertaken, if possible upon a somewhat smaller blank than those I used. A tool with a thinner tip is suggested and this could be ground away as required until measurement of the tooth gives the required result. Having said that I expect there is a simple method of arriving at the correct tool form, if so, I for one would be delighted to learn of it. To *be concluded (Photocopies of "Base Circles" article can be obtained from our Reader's Services Dept. at this address - Ed).*

SHAPER-CUT GEARS

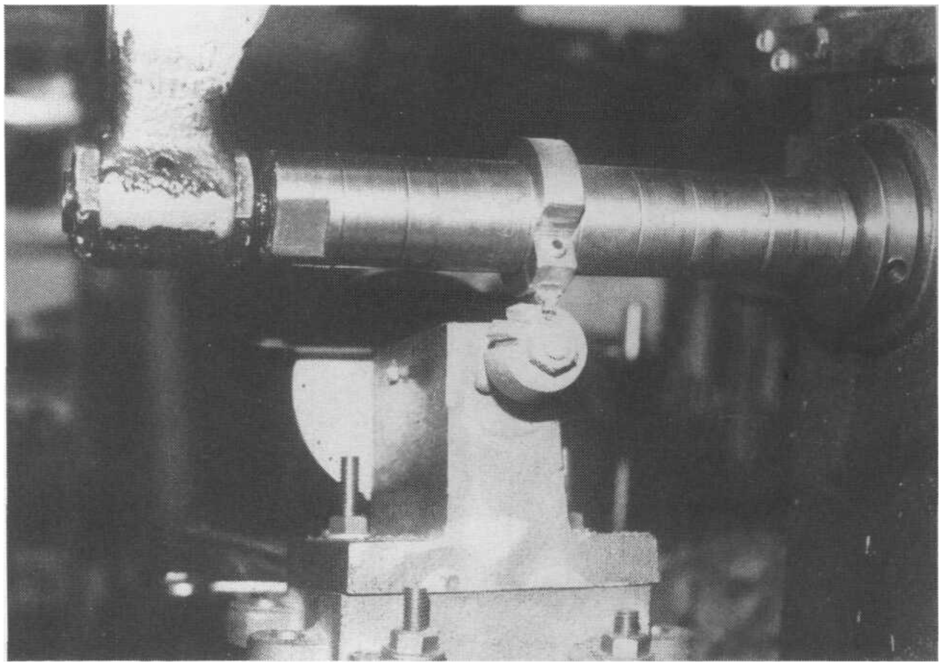
Australian reader C. Bamford decided to build traction engines. He chose to make all the spur and bevel gears first, using milling machine and shaper

Part II (conclusion), from page 112

Part I of this mini-series told how the Author adapted a method which was described in Model Engineer, *14 September 1950, to produce gears for his Fowler traction engine. He described how he got over problems of rigidity which arose. This time he goes on to discuss the methods adopted to produce the spur and bevel gears for the model. He then talks about making keyways for various components.*

With the spur gears successfully completed attention was focussed upon the bevel gears and pinions for the compensating gear (differential). Messrs Plastow's design calls for two 44T gears and two 9T pinions per engine. He offers a specialised gear cutting service. However, having satisfied one minor ambition by producing the spur gears, I wished to pursue the project to completion by producing these more complex items.

Back issues of the *Model Engineer* had provided a number of solutions, the most attractive being a method of cutting to a parallel depth. The method has advantages over conventional methods in that neither specialised machinery nor non-standard cutters are required. Mr. Minchin, who described the system in *Model Engineer,* 15 November 1964, claims that power transmission is 80% of conventional gears, but for my purposes (and I suspect most others) this small loss was of no moment. Again, this seemed to be a simple and elegant solution requiring only the use of a horizontal mill.



Above: ***Fig. 8 shows the set-up for pinions, tapered packing plate and blank holder.***

Machinery Used

As mentioned in the previous article I own an old Carter and Hakes No. 2 milling machine. This would seem originally to have been belt driven from an overhead line shaft and is clearly a production machine. Judging by certain wear it has had a hard life. It came into my possession in the late 1960's for £5 and has been given a new mandrel, extended longitudinal table traverse, chain drive and a graduated screw for vertical travel. An oddity is that both longitudinal table travel and vertical feed can be traversed by a lever operated rack and pinion. Four speeds are obtainable, through what I understand, is a 1929 B.S.A. motor cycle gearbox.

Reading and re-reading the article I decided upon a method somewhat different than that described by Mr. Minchin in that he used a dividing head to index the blanks, using vertical feed for the gears. My milling machine has no power feed for vertical travel and so I was looking for a method to utilise the table feed. Also, although owning a Myford dividing head, I felt it might not be rigid enough for the very heavy work envisaged.

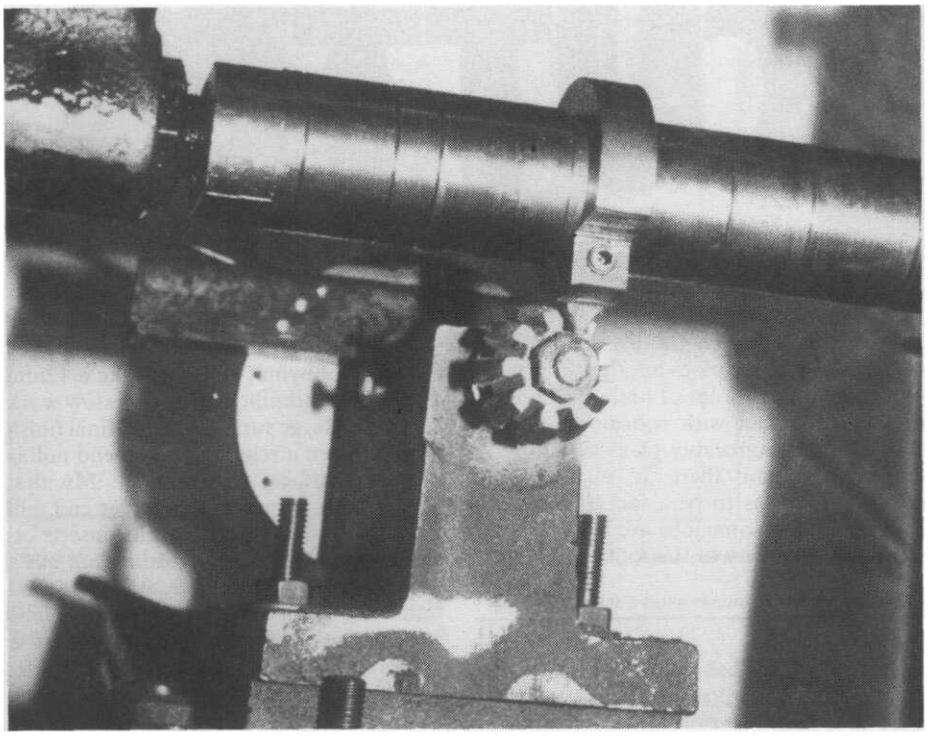
Having decided upon a method, I was fortunate in being able to contact Mr. Minchin and he most generously amplified his article and provided drawings of blanks and cutters. The cutters proved to be of quite simple shapes and he suggested silver steel, which in the event proved very satisfactory.

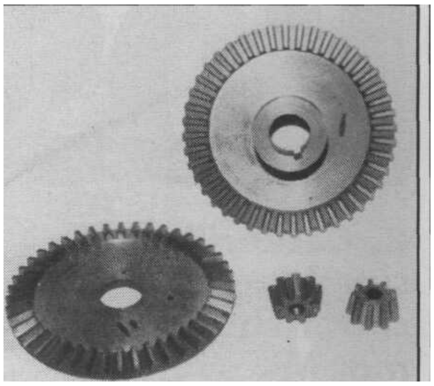
Fig. 8 shows the basic set-up. A packing plate machined to a taper of 11 1/2 deg. to match the pinion and bevel angles is bolted square across the miller table. For the pinions the fixture previously used to rotate the spur gear blanks was fastened to the packing plate and the blank bolted thereon.

Indexing Arrangement

Fig. 9 shows the indexing arrangement. An odd length of angle is bolted to the rear of the blank holder and a circle of plastic to the shaft. Nine indexed holes are drilled through the plastic and three in the angle. The method calls for a central roughing cut and one each side with the cutter offset by 25% of the pitch with the blank rotated in the same direction also by 25% of the pitch. This was achieved by indexing the plastic direct to holes above and below the gashing index hole drilled through the angle. Spacing was taken from indexed holes drilled when dividing was carried out. Movement of the cutter was effected by means of appropriate washers upon the mandrel.

Cutting proved to be quite free in the

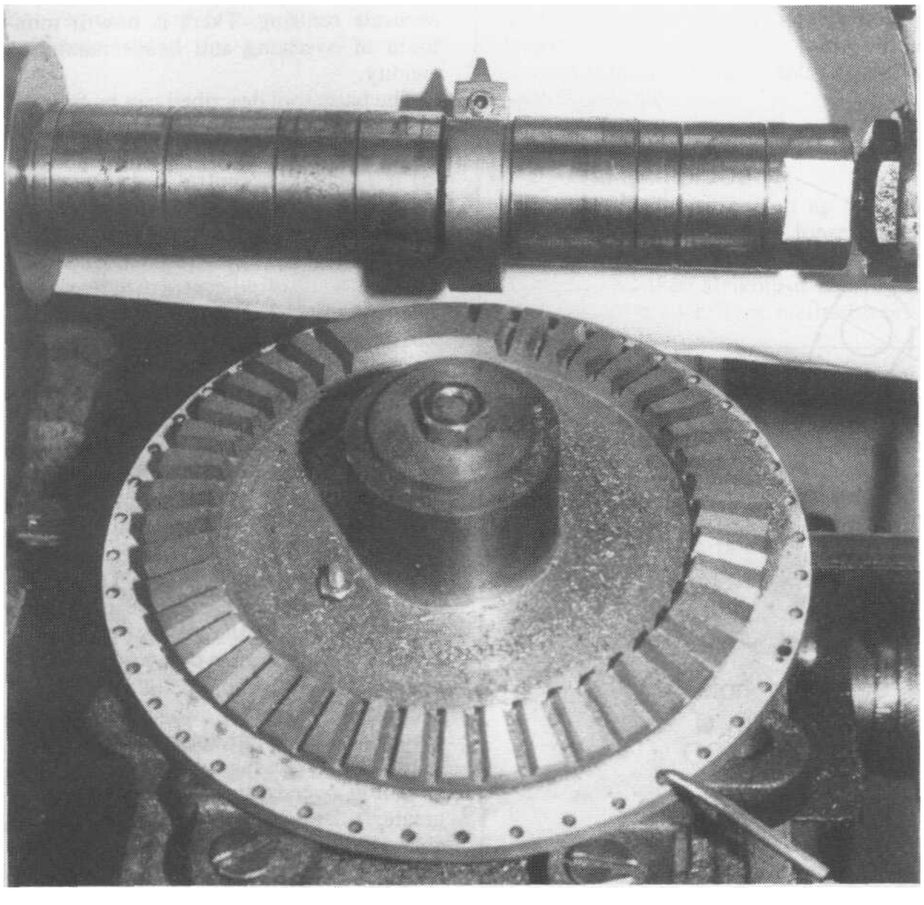




Above: ***Fig. 9 shows offset cutting. The cutter holder is offset by removing the washer, pinion rotated and indexed to the top hole in the angle.***
Below: ***Fig. 10 shows climb milling the bossed bevel gear. The indexing details are apparent in this view, as is the simple tool shape of 20 deg. included.***
Above right: ***Fig. 11, one set of completed bevel gears and pinions.***

cast iron used, at the slowest table teed. Fig. 9 also shows the first offset cut. Both washers are to the left of the tool holder and the pin is indexing in the upper hole in the bar. Also visible is the simple tool holder and the indexing holes.

For cutting the bevel gears the angled packing plate was modified to accept a stub of metal to locate the gear bore with an extended stud, nut and washer for clamping purposes. A countersunk screw and nut affixes the blank to an indexed disc and holes, at suitable spacing, are drilled into the packer. Fig. 10 shows the method and the simple tool used. Because of the boss in one gear, the table feed had to be



reversed for this blank and the table clamp adjusted to withstand climb milling forces. Again, cutting was quick and clean.

One of the most serious problems was to locate the blank centrally beneath the cutter and this was achieved using square and caliper. The appearance of teeth being offset in the figure is an optical illusion.

Fig. 11 shows a set of completed gears, which were a pleasure to make, and which mesh perfectly, although by the time both sets (for two engines, remember) had been completed a certain tedium had set in. This was dispelled by passing to the keywaying operations.

Keyway Cutting

A number of the gears slide upon four splines and others are keyed to their shafts by the usual single key, and a method was devised to use the shaper to form keyways in the gears.

The angle plate previously described was set, short angle vertical, upon the Myford boring table and a 1.25 in. dia. hole bored through. A turned plug was indexed for four 1/8 in. dia. holes, clamped to the bored angle plate face and the holes transferred to the plate.

Gears requiring four keyways had a single hole drilled at the correct pcd and a stub of 1/8 in. dia. metal pressed in lightly, locating in each of the four holes in turn thus locating keyways accurately. Each gear to be keyed was arranged to have a 1.248 in. dia. spigot for locating into the bored hole, the spigot being removed as a final operation if not required.

Bore diameters varied from 0.6 in. to 1 in. and key widths from $^5/_{32}$ in. to $^3/_{16}$ in. A suitable tool holder was affixed to the face of the vertical slide of the shaper which has a convenient 5/8 in. diameter hole being utilised for the purpose.

Once the cutter was centralised, the table was locked and cutting proved quick and easy, depthing was by using the slide's graduated collar. Unfortunately the photograph taken of the operation met with a mishap, but the concept is simple and, I am sure, well known to many.

In conclusion, a most rewarding project which gave me much pleasure and which taught me a lot, not least that the methods most generously described by *Base Circle* and Mr. Minchin work, and work well. My thanks to them both.