ELEMENTS OF SPHERICAL TURNING

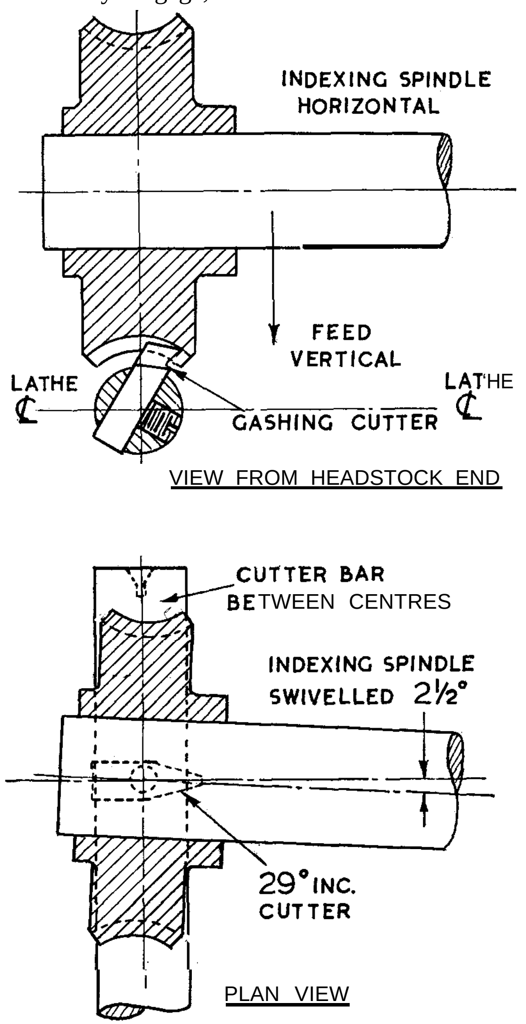
Part IV *Continued from June 2*

by Edgar T. Westbury

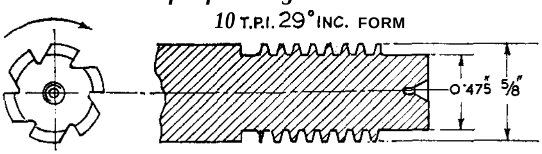
THE SPECIFICATION of the worm and wheel for this appliance (parts 8 and 9) are subject to modification to suit available material. There is considerable latitude in the size of these parts, and the ratio of reduction need not be strictly adhered to. Gearing obtained from breakdown of " surplus " apparatus can, therefore, be used if it is anywhere near the stated dimensions, and a straight-cut spur gear can be suibstituted for the worm wheel, if the wormshaft is set at the appropriate pitch angle as in the vertical-pivot appliance previously described. A ready-made worm and wheel of 40: 1 ratio can be obtained from Bonds o' Euston Road (Cat. No. 7/33), the dimensions of which are larger than those stated on the drawings but within the permissible limits. This particular item has the worm machined integral with the shaft; It is possilble that a worm bored to fit a separate shaft may also be available, but if not, it is only necessary to modify the wormshaft bracket (part No. 10) and its location on the bearing block (part No. 2).

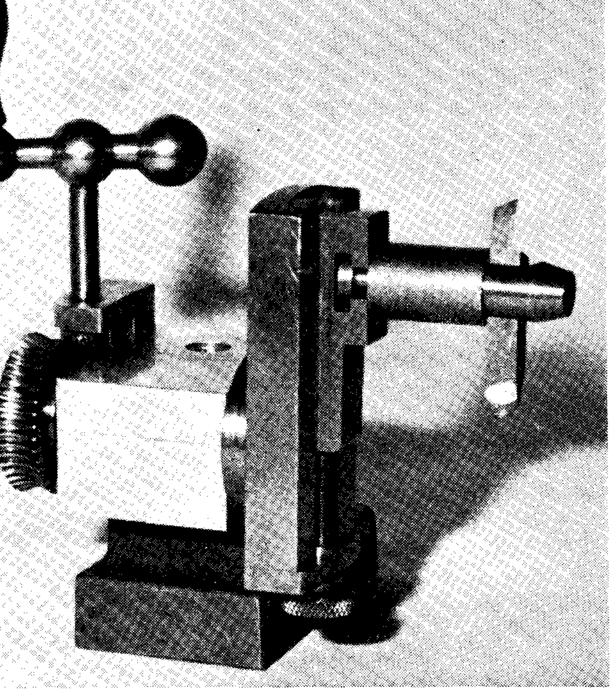
Mr Cohen decided to make the worm gearing himself, and has taken pains to work out the details for machining the essential parts. There is a good deal of unnecessary apprehension about the problems of cutting gears, in general, and worm gearing in particular. It is perfectly true that if gears are required to run at maximum efficiency such as for power transmission, where maximum ratio of output to Input Is essential, both the dedgn and production must be accurate within very close limits. But when the object of the gearing is simply to translate the speed and direction of control movement, and the duty is very light, approximate accuracy of tooth form and other factors is sufficient for all practical purposes.

Most worm wheels are " throated," that is, made with a concave periphery to increase the contact area of the teeth of the wheel in mesh with the worm; but this is not absolutely necessary, and there are many examples to be found of worm wheels with flat crowns in dividing gear and other machine tool applications. In any case, true contact of the worm and the teeth of the wheel can only be maintained over a limited width. Little if anything can be gained by making the throat of the wheel engage more than 90 deg. of the worm thread. All throated worms must be designed to suit the diameter of the worms with which they engage, the concave radius of the



Right: Set-up of worm wheel blank for ***gashing teeth.***
Below: Hob for finishing worm wheel teeth.





Mr Cohen's spherical turning appliance. Note tke worm gear.

throat being equal to .that of the root of the worm thread, plus clearance allowance. If the teeth are cut by a hobbing operation, the throat can be left slightly oversize, as the hob will produce the exact contour required.

It is generally advisable to make the worm first, as it can be used as a gauge for meshing with the wheel. The specified pitch is 0.098, and as the worm has a single start, this is also the " lead," at which the thread is cut. The nearest approximation to this which can be cut on a normal screwcutting lathe is 10 t.p.i., which is close enough for this purpose. A narrow gashing tool may be used for cutting the thread nearly to its full depth, but a carefully ground form tool with sides at an included angle of 29 deg., and a width of 0.031 in. at the tip is required. A narrower tool may be used if after cutting to full depth, the sides of the threads are shaved to produce the width by adjustment of the top-slide. The operation will be facilitated if a material of good machining quality is used, and ample lubrication by cutting oil or soluble emulsion is supplied.

Having turned the worm wheel blank to external dimensions, it should be mounted on a mandrel for cutting the teeth. There are various divergent opinions on now this can best be done with limited equipment; It is often said that worm gears can quite easily be cut by using an ordinary screw tap as a hob running in the lathe and mounting the blank to turn freely on a vertical spindle at centre height. When fed into cutting contact with the tap, the blank will rotate at its natural rate, and cut the teeth progressively to the required depth-at least that is the theory, and it is sometimes known to work, on worm 'wheels in which neither the pitch accuracy nor the number of teeth are of very great importance.

I do not recommend attempting to cut the teeth in this worm wheel by the above method for these reasons: first it is not generally possible to engage the hob to full depth and, therefore, it *will* start cutting on a larger diameter than the designed pitch circle. As a result, rotation of the blank at its natural rate will tend to produce a larger number of teeth than required, and not necessarily an *exact* number, so that there is a risk of double-tracking or uneven indexing of the teeth. The use of an ordinary screw tap of Whitworth or similar thread form will produce teeth of excessively wide pressure angle, though this may be acceptable for some light duties. But the wide fluting of a standard tap may cause their threads to lose contact with those of the blank for parts of the revolution, giving still further cause for mis-tracking or mutilation of the teeth.

In my experience, and in that of Mr Cohen, the best way of cutting the teeth of worm gears, in the absence of proper gear hobbing machinery, is first to gash the teeth to near finished depth by individual indexing, and then finish them by freely floating the blank against a hob of the same diameter, tooth form and pitch as that of the worm to be used. The hob may therefore, be cut at the same setting as the worm, preferably in tool steel which can be hardened and tempered, though mild steel hobs, case-hardened, have been successfully used for finishing one or two worm wheels.

The teeth of the hob, up to about six in number, may be milled or filed, with the cutting faces as near radial as possible. They should be kept fairly narrow, but a little in excess of the thread depth; it is not necessary to space them evenly. Backing-off is hardly possible but a little easing-off of the crests of the threads, by honing, is helpful, and the cutting faces should be honed keen with a slip stone.

In order to set up the blank for gashing the teeth, some form of indexing device is required, but this can be of a simple or even primitive nature, such as a spindle on one end of which the blank can be mounted, and a division plate or a 40-tooth change wheel on the other. A detent or latch to lock this in the required positions is necessary, and the bearing for the spindle may be in the form of a block mounted horizontally on a vertical slide. A single point cutter, fitted to a cutter bar bebween centres, may be used for the gashing operation; its form may be approximately the same as that used for screwcutting the worm, and the depth of cut, applied by the vertical feed, about 1/16 in. The spindle needs to be set with its axis at the pitch angle of the worm, by swivelling the base of the vertical-slide to an angle of 2.5 deg. to the square position, checked with the aid of a protractor from the edge of the cross-slide.

Some care will be necessary to set the position of the blank centrally, both laterally and cross-wise, in relation to the cutter. Exact measurement may be difficult, but after setting by eye as closely as possible a shallow witness cut may be taken on one tooth, and the blank turned into a position where this is readily visible for inspection. When set, the saddle and cross-slide should be locked, and each tooth in turn gashed by feeding the blank vertically, preferably to a positive stop if this can be arranged. The cutter bar is then replaced by the hob, the indexing gear is released so that the blank can turn freely, and the spindle set square with the lathe axis. With the hob fully engaged with the indexed teeth, the lathe is run at moderate speed, and vertical feed applied until the teeth are formed to their finished shape. As the pitch of the worm is very slightly greater than that specified, the teeth of the wheel should be on the minus side in depth rather than otherwise. It will readily be understood that the *circumferential* pitch of the teeth is proportional to the diameter measured on the working pitch line

It may be thought that a good deal of space has been expended on a component which is hardly relevant to the main subject. The basic principles of spherical turning do not directly involve worm gearing, and it is only incidental to the construction of appliances which have been described. But advice is often sought on methods of cutting worm gears for use in various kinds of small mechanical appliances, and it is hoped that this description will be found generally helpful. There are other ways of making worm gears, some of which may produce higher accuracy or efficiency, but their design may involve the use of formulae, which is not easy to apply in practice with equipment normally available.

The shaft to which the worm gear is fitted (part No. 11) may be made from 1/4 in. b.m.s. if it can be chucked truly for turning down and threading the end; otherwise it is better to use larger material and machine it all over between centres.

To be continued

JEYNES' CORNER

Continued from page **610**

It will be seen that Bourne was experimenting with liquid fuel as early as 1834; he also used steam power for riveting in this year. Here are a few of Bourne's early pa'tents :

1834 : Marine engine governor.

1836: Single eccentric reversing link-motion. This, however, did not reverse the lead.

1837: Steam starting and reversing gear for marine engines. Fitted in SS *Don Juan* 1837.

1838: Marine return tube boiler, having forced draught and superheater.

1838: Steam donkey pump for boiler feeding.

1852 : Impulse valves.

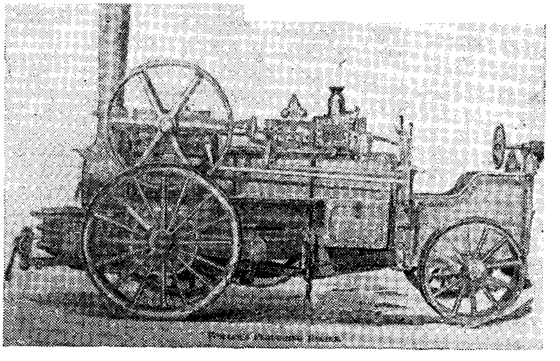
1852 : Balanced crank throws.

Bourne also initiated the superheating or re-heating of the exhaust of the high pressure cylinder of a compound engine, to replace the heat lost by radiation, and produce more power in the low pressure cylinder.

Among the books written by Bourne are: " The Catechism of the Steam Engine," " Recent Improvements in the Steam Engine," " A Treatise on the Steam Engine," "A Handbook on 'the Steam Engine " and"A Treatise on the Screw Propellor."

Bourne also had something to say about the term Nominal1 Horse Power: " The uncertainty and varying character of the ratio subsisting between the actual and nominal power is a source of much perplexity, and proposals have been made in consequence to substitute some other unit for the horsepower. In the average class of modern engines (1869) the actual horsepower may be taken at 4 to 4-1/2 times 'the nominal. The actual and nominal powers of engines, at first identical or nearly so, soon began to diverge; and in time as the pressure of the steam was increased the actual power became twice greater than it had been at first, while the nominal power being an expression of the dimensions of the engine remained the same. The divergence however did not stop here, but has gone on increasing, until in recent engines, the actual power exerted has been in same cases nine times greater 'than is represented by the nominal power."

A Fowler double-drum ploughing engine built in 1867. The late C. E. Shackle built a model of this engine which is now in the Science Museum.



In conclusion, I would say that it at once becomes apparent that confusion has existed on this subject for over 100 years.