ELEMENTS OF SPHERICAL TURNING

Part II Continued *from May 5*

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WHETHER the device employed for producing spherical contours is simple or elaborate, the very first principle to be observed in its operation is the location of the centre around which the generating tool is rotated, by means of a hand lever or other means. This was referred to in the previous issue, but in view of its importance, further explanation of it is given in Fig. 9, which shows the effect of displacing the pivotal point in either direction. If carried to the extent indicated, the error is readily visible to the eye, but for work in which high spherical precision is necessary, even the smallest discrepancy may spoil the finished results. For this reason, some positive means of locating the pivot centre on the cross-slide or bed of the lathe is an advantige, and in some cases may be absolutely essential.

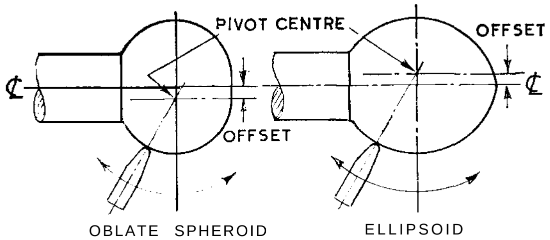


Fig. 9. Effect of inaccurate location of spherical generating tool.

In general work, some method of radial adjustment for the tool point, to deal with varying sizes of work, is equally important; it is also an advantage to provide the smoothest possible feed movement of the rotating tool fixture. But it may be mentioned that in commercial production, spherical curves of fixed dimensions, over a limited angle of arc, are accurately produced by methods and appliances which do not provide either of these facilities. Components such as ball-and-socket joints for motor car steering and suspension systems, in which smooth articulation is absolutely necessary are often finished to close limits of precision by means of a hollow grinding wheel, running at high speed on an axis at 45 deg. to that of the work, as shown in Fig. 10.

The spherical arc generated in this way is usually limited to about 90 deg., which is sufficient for the particular purpose, provided that the rest of the surface is undercut or relieved, as indicated in the example of work dealt with. In order to maintain the uniformity of the spherical diameter despite the inevitable wear of the grinding wheel, it is dressed, when necessary, on the front flat face only. The same generating principle could be applied to the use of a cutting tool such as a hollow milling cutter. Increasing the angle of the tool axis in relation to the work would enable the spherical arc to be extended within certain limits, but it would always leave either a cone or a flat on the front end of the work. It is just as important, however, to observe the first principle, in locating the axis of the grinding or cutting tool so that it exactly intersects that of the work.

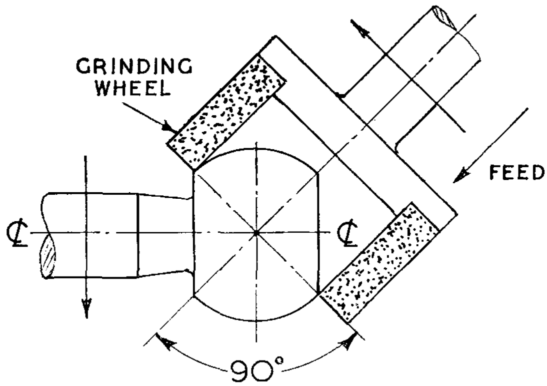


Fig. 10. Method of generating spherical contour with hollow grinding wheel.

It has already been mentioned that many ingenious spherical turning appliances have been produced for use on the lathe, either by manufacturers or lathe users. Fig. 11 shows a typical example of such a device, ‘based on, but not copied exactly from, an exhibit seen many years ago at a ME Exhibition. It is designed to be Mounted either on the bed or cross-slide of the lathe by means of two bolts, and it incorporates a geared rotary movement, in conjunction with a radial tool slide. As an example of machine tool component design, it deserves commendation, and the mechanical details are well made and fitted.

The worm gear provides an adequate turntable for the radial slide, with a broad under-surface to form a thrust bearing, with adjustment for end play from below, in the recessed bolster plate. A removable gauge pin, cut away to the centre to facilitate radial measurement, is fitted to the centre of the worm wheel. The radial sliding member is fitted with a gib for adjustment, and is moved by a feed screw with a balanced handle, hating an indexed sleeve, though the markings on it are not visible in the photograph. A lantern type of tool post, with rocker adjustment for the tool height, is anchored in a T-slot which enables the latitude of radial movement to be extended. Smooth and steady motion of the rotary traverse is facilitated by the worm gearing, and the worm shaft is fitted with a flexible drive, so that it can be operated from any convenient position, or even coupled to a self-acting drive if required,

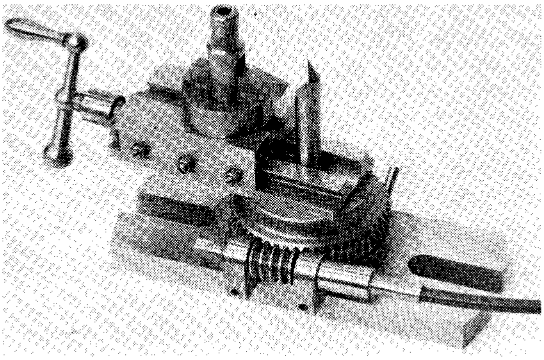


Fig. 11. A worm-geared spherical turning appliance.

The utility of this appliance, however, is restricted in certain respects, wherein its refinements may, En fact, constitute a handicap rather than a practical advantage. In the first place, the vertical height of the bolster, worm gear, and radial slide impose a limit on the size of the work which can be machined on a lathe of small centre height when using the appliance. Though it is likely that most of the spherical turning required will be on parts of small diameter, there are occasions when large work may be encountered, calling for the maximum possible clear swing. The space occupied by the worm gearing, etc., can then ill be spared, and the appliance is at a disadvantage, compared with one having a direct lever feed.

Most spherical turning operations, other than those which are limited to a relatively small arc, involve the need for rotating the tool as far as possible to the left, to carry the curve right down to the neck or stem. When the work is held in a normal chuck, or between centres, the radial slide and its handle may not be capable of swinging far enough round without fouling the chuck or other revolving parts. It is possible to make the handle removable, which helps to some extent, but I have ofttn found that this does not give sufficient clearance. The only thing to be done then is to slew the tool round to the left in the tool post, but though this enables the arc of surface to be increased, it reduces the advantages of fitting a slide which gives direct radial tool adjustment. It will be clear that the movement of the tool slide is no longer truly proportional to the radial adjustment at the actual tool point.

As I have often had to carry out spherical turning, in the course of solving those awkward little machining problems which are passed on to me from time to time, I have devoted a good deal of time to the design of appliances which give maximum facility without serious limitations for work of this nature. The photographs, Figs. 12 and 13, show one of the most useful of these which I have so far been able to (produce. In the drawing, Fig. 14. a few minor modifications have been introduced in order to simplify construction with materials most likely to be readily available.

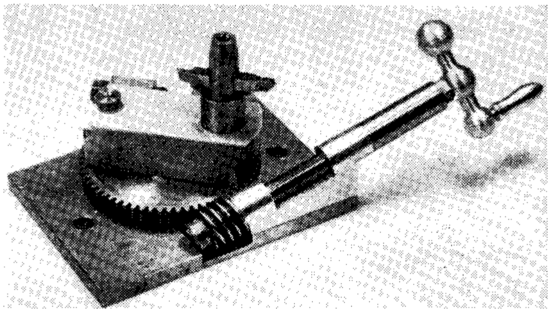
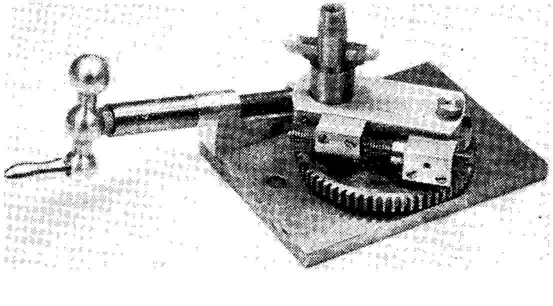
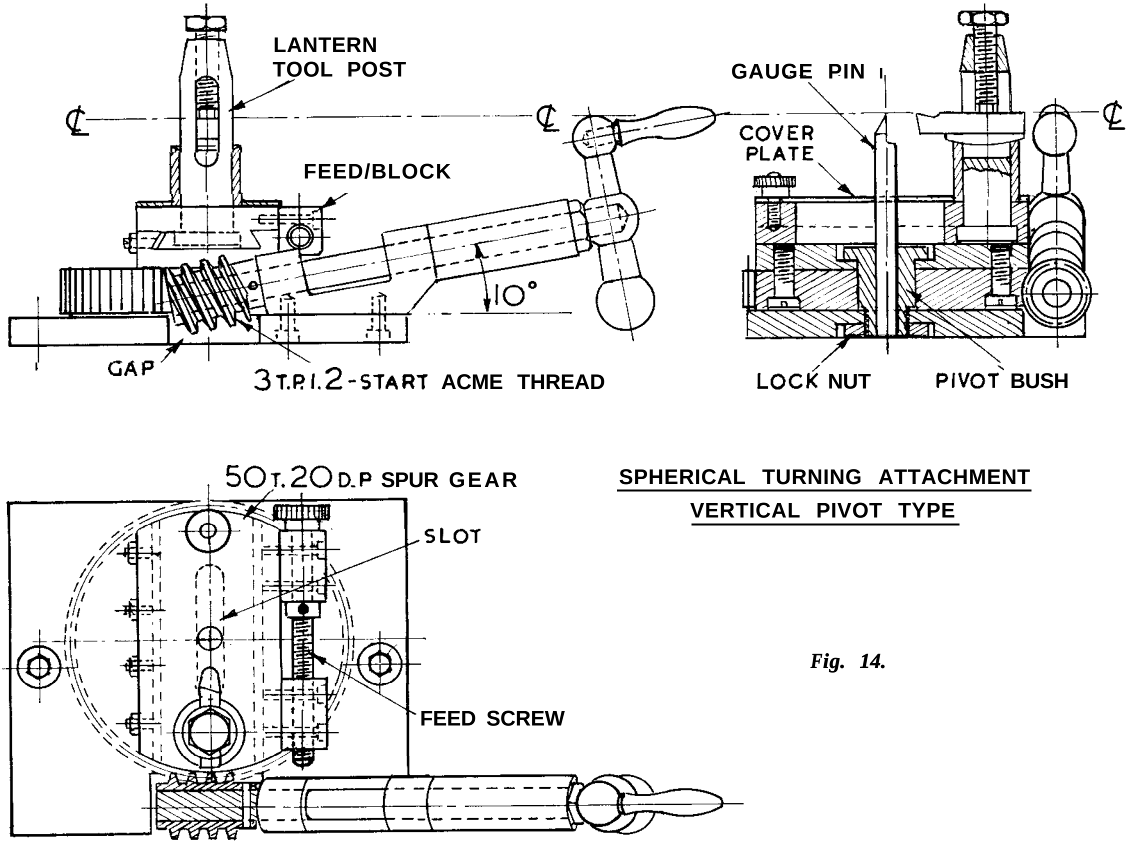


Fig. 12. A spherical turning appliance with oblique wormshaft.

The base of the appliance is a rectangular piece of 1/4 in. steel plate, scraped flat and true on both sides. For mounting it on the cross-slide of the lathe, two recessed socket head screws are provided, which engage with 1/4 in. B.S.F. tapped holes in a strip suitably shaped to fit the T-slots of the cross-slide. This method, incidentally, can be

Below: Fig. 13. Another view of the appliance showing method of adjusting the radial slide.





SPHERICAL TURNING ATTACHMENT
VERTICAL PIVOT TYPE

Fig. 14.

recommended for securing all sorts of attachments to Tslotted cross or vertical-slides. It facilitates quick setting-up and removal, avoids the need for loose clamps and bolts, or projections which may get in the way of operations. Moreover, they reduce the risk of overstraining the T-slots, by providing increased bearing surface over their full length. The strips can easily be made from mild steel bar by milling or shaping; they should slide easily in the T-slots, with clearance on the top surface, so that they lie below the slide level.

A hole is drilled and tapped 3/8 in. X 26 t.p.i. in the centre of the baseplate, which is recessed on the underside so that a thin locknut can be fitted to secure the pivot bush when it is screwed in to eliminate end play of the rotating parts. As in the appliance illustrated in Fig. 11, worm gearing is used for the rotating movement, but instead of using a proper worm wheel, it makes use of a spur gear with straight axial-cut teeth. The reason for this is to allow the wormshaft to be inclined upwards at a sufficiently steep angle to give ample clearance for the operating handle, over the cross-slide. Whether this shaft is located parallel to the lathe axis, or at any other convenient angle, it allows the gearing to be operated with the minimum interference from other slide movements

The gear wheel actually used for the original appliance was one which happened to be available, in the traditional model engineers' " treasure chest " (some unkind people refer to it as the " jackdaw's nest "). But in order to cater for those who may not be able to obtain a gear wheel of the same size and pitch, the drawing has been modified to show one which may more readily be available. Change wheels of 20 d.p., and with varying numbers of teeth, are used on several popular lathes, and are obtainable as spares from makers or dealers. The 50-tooth wheel shown is a convenient size, but the exact gear ratio is not important. Both sides of the wheel should be flat and parallel on their essential bearing surfaces; recesses, if they already exist in one or both sides, are permissible, and the teeth on the lower side should be relieved.

Worm details

To mesh with a 20 d.p. gear wheel, a worm of 6 t.p.i. will serve for the purpose in view, though it is not perfectly accurate and in fact, calculations are complicated by the angle at which it is presented to the wheel. Perfectionists who insist on everything being exactly right may find, after working out details to the nth decimal point. that the exact pitch cannot be produced by any means at their disposal. In the solution of many engineering problems, approximate accuracy is permissible, and gives quite satisfactory practical results, with certain reservations where the utmost efficiency is absolutely necessary. I mention this because theoretical errors in such matters are often a happy hunting ground for valiant Knights of the Slide Rule; I am not deriding their worthy and often necessary efforts in working out difficult problems in workshop mathematics, but simple methods will often produce the desired results.

The term 6 t.p.i. defines the distances between the crests of adjacent teeth, or in other words the " apparent pitch." This is also the true pitch for single-start worms, but for a two-start worm, the true pitch, or " lead," is 3 t.p.i. To cut this pitch on a lathe having an 8 t.p.i. lead screw, the mandrel/lead screw ratio needs to be 8:3. This can be obtained by using a compound train with drivers of 40 and 50 teeth, and driven gears of 25 and 30 teeth, or any combinations which will give total equivalent ratio. The worm blank may be made in a readily machinable metal, such as brass, as its duty is quite light, and after turning and concentric drilling, may with advantage be mounted on a true-running mandrel to run between centres. The screw-cutting tool is ground to Acme form (29 degrees included angle) and the width at the tip should fit the root of the gear teeth; this is the maximum allowable, as it is often more oonvenient to use a narrower tool and finish the thread by taking side cuts.

The lathe catchplate should be fitted with two equal-sized driving pins exactly opposite to each other, for cutting two-start threads. It is most important that the blank should be quite secure on its mandrel, and the carrier must also be firmly fixed, as shifting of either during the entire operation would ruin the work. If desired, a narrow straight-sided tool may be used to gash out the threads before using the forming tool. In either case, the first "start" should be cut almost to full depth in one position before engaging the carrier with the other driving pin, for cutting the second " start." Finishing the threads may be done in alternate driving positions, at the same tool setting.

It may be mentioned that the angle of the wormshaft is determined by the pitch angle of the worm, which in turn is influenced by its pitch diameter. With an outside diameter of 5/8 in., the pitch angle works out at approximately 10 deg. as shown on the drawing, but this may be subject to slight variation. It may be checked by meshing the worm hard against the teeth of the wheel, with its bearing bracket in position. Any discrepancy in the angle can then be detected easily and, if necessary, corrected by filing the underside of the bracket. A gap will need to be cut to clear the worm when it is located at approximately the level of the worm wheel centre, but this is not at all critical. The bracket is located to give close but not tight meshing, and it is secured by two screws from the underside of the baseplate. An extension sleeve is fitted to the wormshaft to carry the handle well away from working parts, and either a ball handle, or any other type preferred, can be fitted. Incidentally, the spherical curves of the handle shown were generated by its own aid, while a temporary handle was fitted.

A short radial slide is secured to the top of the gear wheel, it is intended for adjustment, rather than traversing in the normal sense. Its feed screw is fitted at the side and does not project outside the turning circle any more than necessary. The slide is slotted so that a gauge pin can be fitted in the centre of the pivot bush, and when this is not in use, a cover plate, held in place by a single knurled screw, can be fitted to prevent swarf clogging the slot. A lantern type tool post, with the usual rocker pad for height adjustment, is fitted to the moving component of the slide.

The radial movement provided is relatively small, but is sufficient for its designed purpose, which is to cope with spherical work up to 1-1/2 in. diameter on a 3-1/2 in. lathe. The tool can be rotated through a full circle without fouling of the moving parts, though this is never necessary or practicable.

ERRATA

HOLCROFT VALVE GEAR

Page 274, column 1, line 6. Should read:
Thus when Angle A = 90 deg *Not* 20 *deg.*

Page 275, column 2, line 9. Should read:
and $337\frac{1}{2}$ deg. *Not* 339 *deg.*

Page 275, column 2. First equation should read:

$$OF = \frac{1.620}{3.939} \times .00894 = .0037$$

So OF = 1.620 + .0037 = say 1.624 in.