ELEMENTS OF SPHERICAL TURNING

Part V *Continued from June 16*

by Edgar T. Westbury

THE thread should preferably be screw cut to fit the rotating and lock ring slide neatly and accurately. It should be a close working fit in its bearing and adjusted to eliminate end play; if the worm wheel is keyed to the shaft as recommended the large headed screw (part No. 16) will provide endwise adjustment, and a fibre washer may be interposed between the lock ring and the face of the bearing to enable slight frictional resistance to movement to be obtained.

Modification of the wormshaft (part No. 13) and its bearing bracket (part No. 10) may be called for if a different worm and wheel than that specified are employed, but the alterations are obvious, and the bracket only needs to be located against the back of the bearing block so that the worm is in close mesh with the wheel eliminating backlash as far as possible consistent with smooth and easy working. In the original version of this design, I used a single bearing with a long sleeve extending upwards, instead of a gapped bracket as shown, the .object being to use a worm which was machined integral with its shaft. If the specified arrangement with the worm a light press fit on the shaft and grub screwed or cross pinned to it, is employed, the gap in the bracket should be made to fit the length of the worm closely, without end play.

The ball handle (part NO. 14) was machined with the aid of the appliance together with other similar pieces of various sizes, such as those seen in the photograph in the previous issue. Some further information on the {methods employed for turning these parts will be given later. Cross drilling and tapping the handle to fit the wormshaft and the crank may present practical problems and, in the first case, it will be found worth while to set the piece up on the four-jaw chuck so that the middle ball runs truly. Before starting the hole with a centre-drill, a light facing cut should be taken to serve as a "witness," when any error in setting up will immediately be apparent, and may be corrected by adjustment of the chuck jaws. The cross hole, in this particular instance, should stop short of passing right through the ball, for the sake of neatness, and a plug tap is then used to produce a blind thread to screw tightly on to the wormshaft. A short piece of 1/4 in. rod, similarly threaded on the end may be screwed into the ball to assist in the orientation of the piece when drilling and tapping the hole in the end ball from the other side for fitting the crank. If this is not done, it may be found difficult to ensure that the two holes are in the same axial plane, and the finished result may be rather unsightly, to say the least.

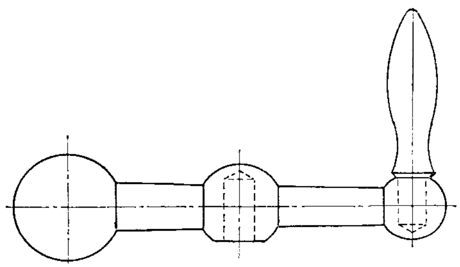
The rotating tool slide is moved by means of a small feed screw (part No. 10) which is quite easily machined from the solid, but it is permissible to make the head separately and pin or otherwise secure it to the shank. Instead of screwing it 2 BA, a 3/16 in. X 40 t:p:i. thread may be used which, besides being more convenient for screwcutting, would enable the head to be indexed in 2.5 divisions, each giving 0.001 in. increments of feed. But, as I have pointed out, this only gives accurate measurement of the work being produced when the tool is applied in a truly radial direction, which Is not always possible, because of limited clearance between the moving parts of the appliance and the lathe chuck when in action.

A groove is turned In the head of the feed screw to fit closely over the thickness of the keep plate (part No. 1.5) which is attached to the end of the rotating slide (part No. 3). This has a U-shaped gap to fit the groove diameter of the screw, thus providing positive location in both directions, without the need for a separate thrust collar. After drilling and tapping the fixing screw holes, the plate is located on the end of the rotating slide, with the feed screw In posibion, in the tapped hole of the radial slide (part No. 4) and the tapping holes spotted through, prior to drilling and tapping.

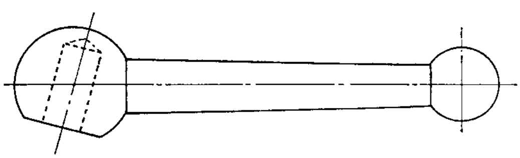
Ball and socket joints

Although the need for precise spherical accuracy is most important In parts such as ball and socket joints, which need to articulate over a universal angular range, many occasions occur in general workshop practice where it is worth while to set up a spherical turning appliance to ensure neatness and genera1 accuracy of the finished component. These include several kinds of fittings for machine tools and attachments within the scope of toolmakers and "gadgeteers." The two examples shown are typical and do not call for explanation. Balanced handles are almost universally employed for slide rest and machine table feed screws nowadays, having superseded the plain crank handles Which were once common. Their primary object, when first introduced, was to avoid risk of inadvertent movement under the effect of gravity and viabration, and this is still of some importance when the handles are large and heavy. Exact balance is rarely necessary for small handles, but the shape has become very popular because of ease of manipulation and pleasing appearance.

Clamping levers for turrets and other fixtures are also commonly made with ball ends, to harmonise with the handles, besides combining maximum strength with production facilities. The shape and proportions of the examples shown are based on examination of a number of parts seen on actua1 machines. Although standardisation of these parts by firms specialising in their produc-



BALANCED HANDLE FOR SLIDE REST



CLAMPING LEVER FOR TURRET

tion, has been introduced, there is still a good deal of variation in details. The balanced handle shown has the large ball twice the diameter of that of the small end; the middle ball is intermediate in size, though in some cases the method of attachment to the feed screw, or the fitting of an index dial may call for modification of its size, and sometimes its shape as well. Small1 handles are often screwed on to the end of the feed screw and locked by means of a back nut, In which case the centre hole, as shown, does not pass completely through the ball but in other cases the handle may be secured by a nut or retaining screw on the outer end.

General proportions

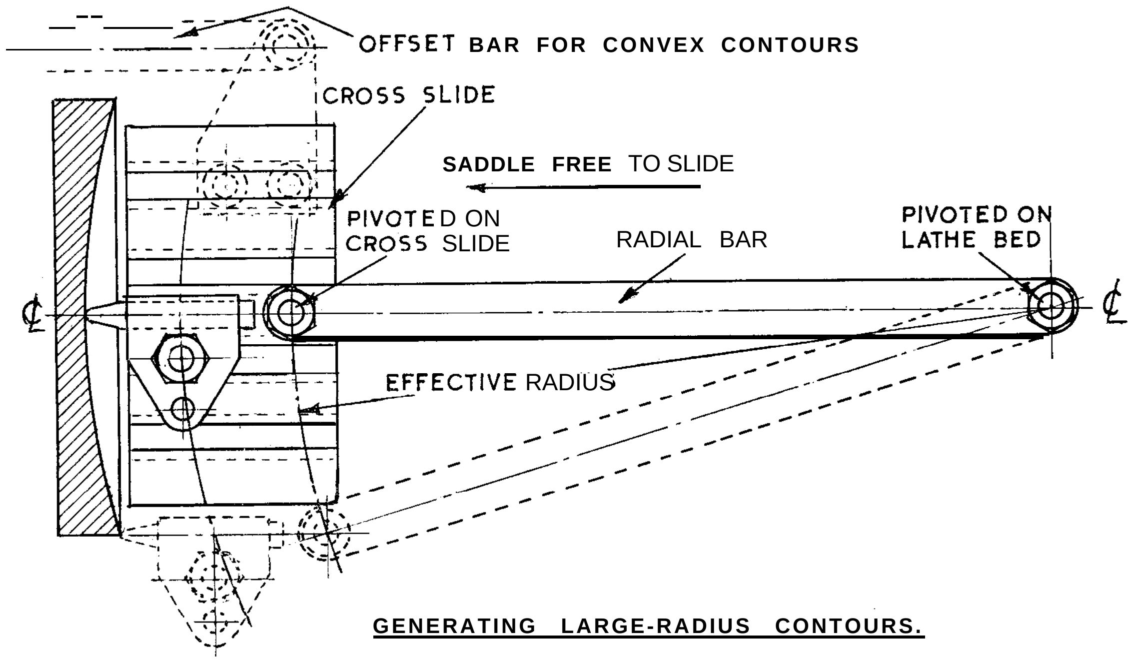
The hand crank has a length approximately equal to the radius of the handle (i.e. half the length [between ball centres) and a diameter somewhait less than that of the small end ball It is necessarily made as a separate part and pressed or screwed in tightly. Unless a contour-forming or copying appliance is available, its shape is best produced by means of hand tools. It is worth while to take pains in shaping it properly, not only on the grounds of appearance, but also for comfort in handling. One often sees rough and slovenly shaped handles, neitiher the look nor the feel of whlich give joy to the operator. The shank of the balanced handle should have a taper of about 2 to 23 deg., total length between ball centres about four times that of the centres ball, and mean diameter about half that of the same ball.

For a clamping lever 2-1/4-in. long between ball centres, the large ball may be made 11/16-in. dia., and the small ball 7/16-in. dia.; other sizes in proportion. The taper may be 2 to 2-1/2 deg. as before, with a mean diameter of about 9/32 in. In most cases levers of this type are cross drillled and tapped at an angle Which is convenient to give clearance over the fixture and fittings to which it is applied, and unless the length of thread on the clamping bolt necessitates drilling right through, a blind hole is preferable for the sake of appearance. The angle of the cross hole in this example is 15 deg., and for drilling the hole, the large end ball can be held in the three-jaw chuck, protected by a sllip of thin soft metal, and inclined backwards at the required angle; this is not at all critical unless demanded by specification, or to ensure uniforrnity in a number of similar components.

It may be observed in passing that solid integral clamping levers of this kind are not only neat, but also provide maximum strength and rigidity ,for their intended duty. Levers made in two pieces, with the handle screwed or otherwise attached to the centre hub or nut, obviously have their torque resistance limited by the strength at the point of attachment, which is often relatively weak. A variation of the lever shown, which may be preferred if the radial length is short, is to shape the shank like that of the hand crank of the (balanced handlle, instead of with a ball end. The area of the clamping surface at the face of the cross hole may be considered too small for ample bearing, but a loose thrust washer may be fitted, and for some purposes it may be advantageous to make this with a spherical under surface to assist self-alignment of the fixture.

Machining procedure

In these, and most other turning operations of a similar nature, roughing out to within about 1/32-in. of finished shape and size is generally advisable. The slide rest tools may be manipulated for part forming of the contour, but, as the spherical appliance is capable of taking reasonable cuts, it is often sufficient to take the corners off wiith a 45 deg. chamfering tool. For the balanced handle the taper shank can be turned to finished size, or leaving only a very small amount for subsequent finishing; one advantage of the horizontal-pivot



GENERATING LARGE-RADIUS CONTOURS.

appliance, when fitted at the back of the cross-slide, is that the normal front too1 can be retained in position without disturbing the angular setting. A tool having angular sides at about 60 deg. inclusive and a small radius on the nose is advised for turning the shank, as sharp internal corners make blending-in of contours more difficult. The two parts of the shank should be machined at the same index setting, so that they form in effect a continuous taper, interrupted by the middle ba1l.

While it is not impossible to form most of the contours on work mounted between centres, it is generally easier to mount the work in the chuck, without back centre support, and machine as much of it as possible ibefore parting off. The small end ball should be formed on the outer end and, if the amounlt of overhang should be considered excessive, a little extra length should be allowed so that a small centre may be drilled to take the back centre; this length is turned down to a small diameter and subsequemly parted off. Sometimes a small axial hole in the end ball is permissisble, such as to take a grub screw to lock the hand crank. If the work can be chucked truly, the turning may be done piecemeal, with only sufficient projecting for the particular part of the operation in hand. After parting off, the large ball may be finished by chucking over the middle ball again protecting its surface with a soft metal slip or ring and pushing it back as far as it will go in the chuck. It is generally possible to get within 30 deg. of the centre in the spherical forming of the large ball, so that not much is left to be machined in the finishing operation. Mention has been made of the cross drilling operations on these components, which involve some problems, as it is not easy to drill exactly through the centre of a ball, or to ensure that the hole is drilled at the correct angle, but detalled instructions on these matters are somewhat outside the scope of the present articles.

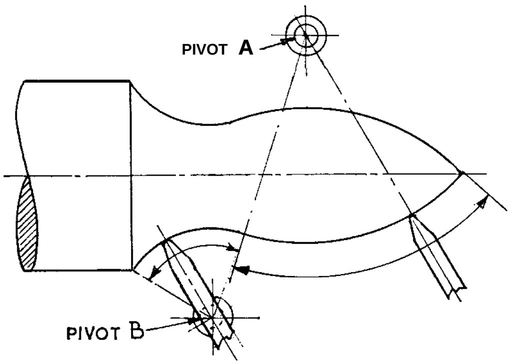
Large radii

Limitations in the radius of adjustment for the tool in any of the spherical turnling appliances described may make them unsuitable for dealing with contours of specially large radius. It is, however possible to cope with these by means of simple devices which follow the same basic principles. Optical instrument work for instance, often involves the need to machine concave mirrors, also laps and moulds for lens grinding, which have a large radius of curvature. The method is shown in my drawing, in which a radius bar pivoted at its two ends to bolts fixed to the cross-slide and the lathe bed respectivly, is employed. In order to produce a true spherical curve, the latter point must be exactly under the lathe axis, and the tool point must be set to coincide with lathes centre-line when in the middle of the work as shown.

With the saddle free to slide and the cross-slide traversed by its feed screw in the normal way, the swing of the slide bar will cause the tool to move in an arc and produce a contour equal in radius to the length of the bar between its eye centres. In a variation of this device, the cutting tool may be carried in a fixture attached directly to a die block fitted to a slot in the cross-slide. The effective radius In this case will then be equal to the distance from the pivot on the lathe bed to the actual tool point, and therefore will be more susceptible to variation or adjustment than when using an articulated bar of fixed radius. Convex curves may be more difficult to produce in this way as it may be impossible to pivot the radial bar on the lathe bed at the required point unless the work is overhung a long distance from the headstock. In this case, it is possible to use an offset radial bar at the back or front of the headstock, provided that this is set exactly parallel to the lathe axis when the tool is in the centre of the work. Ihis arrangement is indicated by dotted lines.

Curved profiles

Sometimes spherical turning appliances can be used with advantage to produce-paradoxically non-spherical contours involving circular arcs. This cannot be done with the horizontal pivot appliance having a fixed centre height, but the simple vertically pivoted lever device, which has the widest range of adjustment for either internal or external curves, is easily adapted to this kind of work. In my next drawing, the convex curve on the end of the work is produced by setting the tool to a large radius from the pivot A, and the concave curve by setting it to a large radius from pivot B.

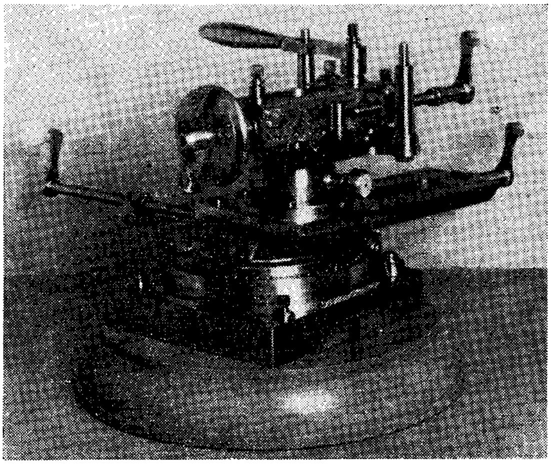


GENERATING NON-SPHERICAL CONTOURS

This principle could be applied to forming the hand crank for the balanced handle, but many turners would conslider it unnecessarily complicated. it was, however, employed to advantage in producing a master pattern for use on a copying lathe, where both the dimensions and curvaures were specified within close limits. Where the convex radius is too large to be obtained with an appliance mounted on the cross-slide, the tool may be controllled by a radial bar having its stationary pivot mounted at the back of the lathe bed, and the other on the cross-slide. In this case, the cross-slide must be set to move freely, and the saddle traversed in the nonmal way, using self-act if desired. This arrangement was employed in a munition factory in quantity production of large shells for forming the nose contour to fine limits.

A compound turning appliance

While on the subject of appliances for spherical turning, mention may be made of an ingenious and elegant device built by Mr. John Pickles, as a part of a set of equipment for ornamental turning. It is intended to be mounted directly on the lathe bed, and its movements provide for many other operaltiion's in addition to spherical turning. The square base carries a turntable with a " tangent wheel "or worm gear, the movement of which is controlled by a crank on the shaft extending to the left. With the centre of the base mounted exactly under the lathe axis, spherical curves can be produced by a cutting tool mounted on the radial slide, the handle of which extends to the right. Superimposed on this slide is another component capaible of both rotating and radial sliding movement, and also incorporating a bearing for a horizontal spindle. This is fitted with a grooved pulley on its front end, so that it can be driven from an overhead shaft, and a cross-slide carrying a socketed tool holder. it is thus possible to use the spindale for drilling, grooving, fluting and eccentric cutting or " engine turning," on flat, angulacr or spherical surfaces of work held in the lathe chuck.This appliance, together with a geometric chuck, was awarded the Bowyer-Lowe Cup at the 1958 M.E. Exhibiition.



A spherical turning slide rest built by John Pickles.

Allthough complex movements such as provided for by this appliance are rarely required in machining colmponents in general engineering, they demonstrate how inexhaustible is the range of

Continued on page 652

SIMPLEX

Continued from page 649

rather more than 1-1/4 in. wide, machine this, using the four-jaw, or by milling to exactly 1-1/4 in. wide, or If the frame slots have already been cut and finished-to a tight fit in the horn slots. Drill all the holes in the horns, noting that the top and bottom holes must not be too close to the ends or there will1 be no room for the bolts holding the top and bottom stays. Jam the "gauge" into the first horn slot and clamp the horns, in pairs, to both the frame and the gauge, using two small, and one medium-sized clamps. Run the drill through the holes in fhe horns and drill the frames. Remove aI1 parts and clamps, take off any burrs, and countersink the outside of the holes in the frames. The rivets required here are 1/8 in. X 1 in. iron snaphead, and these should be just about the right lerrgth as bouglht.

Feed pump

The most simple method possible to get water into the boiller is probably the single-ram eccentric-driven pump, or an externally fitted crosshead pump. I would have liked to have shown a cross-head pump, similar to that on ***Rob Roy*** but the Walshaerts valve gear rather gets in the way. It would just be possible to sling a crosshead pump of small bore underneath one of the cylinders, and drive it by an extenslion of the drop link or by a separate link bolted to the crosshead. The snag of this arrangement is the large offset necessary, introducing an unpleasant couple. This would quickly cause wear on the crosshead slippers and then on the piston rod gland.

If we use a single ram eccentric-driven pump between the frames, the large bore and stroke necessary to ensure that the pump is always master of the boiler becomes rather a nuisance, and might cause jerky running at low speeds. But reading through a recent article on pumps by Edgar Westbury gave me the idea of using a differential double-acting pump, so that only one eccentnic and eccentric rod and strap will be needed.

To be frank, I am not too certain of the effective output of the pump shown, so I have purposely arranged for a fairly large bore and stroke. Experienced builders who intend to fit an injector in addition may be well advised to make the throw of the eccentric 7/32 in., ratiher than 1/4 in., which will reduce the anguliarity of the eccentric rod quite considertibly. 1 should however explain that as the pump has not .been drawn exactly to scale, allthough the dimensions are correct, the eccentric rod appears shorter in proportion to the other components than it really is.

The pump is bolted to a cross-stretcher cut down 3/8-in. thick b.m.s. by four 2 BA hexagon-headed bolts, though Allen screws would be preferalble as there must be no chance of the pump working loose in service.

This crossstretcher is in turn bolted to the frame.s by three 4 BA screws each side. That on the right in my drawing should be countersunk, to clear the driving wheel, but the other two may be turned bolts, to ensure a good fit in the frames. In addition, after the bolts have been tightened up, a 1/8-in. silver steel dowel pin should be put in, a good fit In frame and stretcher, to take some of the thrust of the ram off the screws. There is just room for this between the two bolts.

To be continued

SPHERICAL TURNING

Continued from page 644

operations which can be carried out on the lathe beyond normal turning as generally understood. Lathes designed specially for ornamental turning a century or more ago were often equipped with a galaxy of appliances, few of which, I imagine, were ever properly mastered by a majority of those who used the lathes.

There are many possible variants of the sphericall turning appliances I have described, all capable of accurate work provided that they follow the basic principles. I have seen a simple horizontal-pivot attachment used on a capstan 1athe for production work, the spindle worked in a square block held in the tool post of the cut-off slide, and the cutting tool, adjustably mounted on its from flange, was presented tangentially to the work. Rotation of the tool head was arranged so that it could be linked to the capstan for self-acting feed.

Modern users of lathes are generally satisfied with straight forward slide movements, which will generally cope with most machining requirements. Many readers may say "these gadgets do not concern me, I shall never need to do spherical turning or other fancy work!" But one never knows when the need for special operations may arise, and when it does, it is allways urgent. The " compleat " turner (to borrow a term from Izaak Walton) should always strive to attain a comprehensive understanding of both the possiblities and the limitations of his machine. It was said by Joshua Rose, a well known 19th century writer on workshop subjects, that " he who is master of the lathe is master of the entire mechanical world."