Turning a Radius on The Lathe

From time to time, articles appear in the model engineering press describing the use of coordinates as a means of generating a radius or ball. In his book, Guy Lautard[1] gives a very readable and detailed description of the method. Roughly half of the book is taken up with tables. It is well worth its cost, and Mr Lautard highlights several potential pitfalls, some of which I have already tried successfully.

The approach used by Mr Lautard and others divides a quadrant into equal angular steps and calculates X and Y coordinates using the sine and cosine of each angle. Having made the incremental cuts, the component is rounded off by a file or abrasive. The technique works fine and is handy for creating radii which are not dimensionally critical. It is also an effective means of producing more general profiles. As an example, Mr Lautard provides a set of coordinates for turning a profiled machine handle. The flexibility of the technique is a great attraction, and the user is not restricted to the use of circles when producing some desired shape.

However anybody who intends to make a large number of ball handles or requires accurate radii would benefit from the use of a radius generating tool. This may be no more than a form tool such as that described by Professor Chaddock[2]. Aficionados of ball turning might prefer something like Mr J. A. Radford's[3] spherical turning tool.

For greater flexibility whilst retaining simplicity, Stan Bray's[4] radiusing tool is very neat and represents a good learning exercise in toolmaking. The diagrams in Stan Bray's book are not dimensioned, but individual needs vary and there is no need to be too prescriptive. Stan Bray's theme is to encourage the individual to adapt whatever materials are to hand. Ian Bradley and Norman F Hallows[5] illustrate a similar tool.

These tools are set up so that the axis of rotation of the work lies in the cutting plane. If the tool is not exactly at the lathe centre height, the workpiece axis of rotation will lie parallel to the cutting plane. An obvious effect of this is that a "*Nib*" will remain on the ball. Other, less obvious effects are that the turned radius will be greater than the radius about which the cutting tool is rotated. Furthermore, this effect diminishes as the radius of the cut increases. Consequently the machined profile will not be perfectly spherical. An ellipsoidal form will be generated.

Similarly unless the axis about which the cutting tool is rotated intersects the axis of rotation of the workpiece, a correct sphere cannot be produced.

The extent of elaboration which can be achieved is illustrated by J H Evans[6]. Some of the techniques described by Mr Evans are really milling processes.

While all these wonderful possibilities float around in my mind, I stumble from day to day without ever knowing what is in store.

I may not have a radiusing tool, but the coordinate method described in the articles referred to above is satisfactory, and it is always to hand. I enjoy doing a bit of maths. It gives me an excuse to avoid the thing I am supposed to be working on.

However, the method used by Mr Lautard and others in which equal angular steps are employed has the disadvantage that successive increments in both X and Y are different. I could never bear to blame myself for being unable to follow instructions, so I decided to regard this approach as error prone, preferring to fix the step size either in X or in Y. In my opinion this made for a simpler implementation, and after careful discussion concluded that I was in complete agreement with myself.

I also realised that in generating a ball, it made sense to swap the roles of the two axes after the 45° point was reached. Thus if the crossfeed steps were initially constant and the tool was fed longitudinally by a different amount at each step, then after the 45 degree point, the longitudinal axis would be incremented by constant amounts and the crossfeed distance would be altered to suit.

The reason for swapping, is that at the extremes of the radius being generated, one of the coordinates changes much more rapidly than the other. This can be seen from examination of Figure 1.

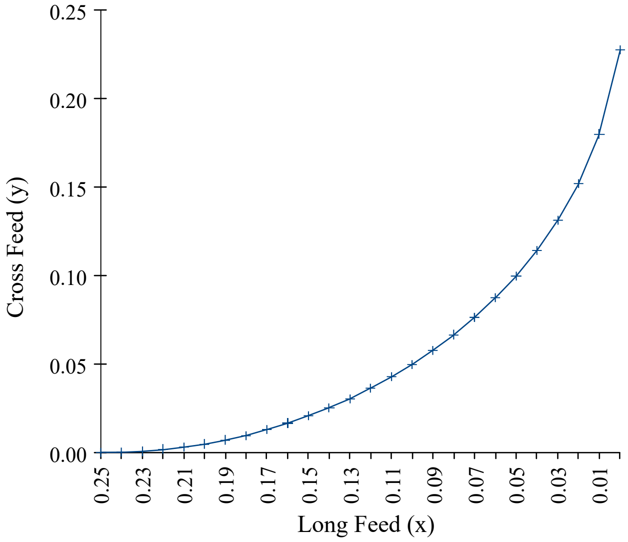

Figure 1. Hemispherical profile of radius r =0.25" using coordinates.

Setting the position of an axis with a high degree of precision is difficult. The situation is exacerbated when the required position falls between dial graduation marks. Incrementing one axis by a predetermined amount so that all settings on that axis coincide with dial graduations should minimise the setting error on that axis. Cutting along the second axis to a distance calculated to correspond with the predetermined increment of the first axis restricts the principle source of error to the second axis.

In practice the process of smoothing the finished article would probably introduce imperfections at least as great as those resulting from errors in the axis positions. Convenience of use is the principle benefit of the approach described here.

Using a spreadsheet it is a straightforward matter to implement the relevant equations given below of which the variables correspond to those illustrated in Figure 1. A rough machined ball handle produced by the coordinate method is shown in Photo 1.

$$\theta = \sin^{-1}\left[\frac{x}{r}\right]$$

$$y = r.\cos(\theta)$$

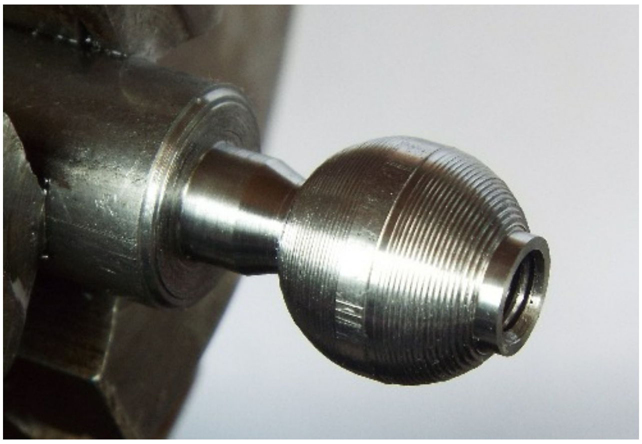

Photo 1. A ball handle produced by coordinate machining prior to finishing with a file and abrasive paper.

While persisting in the use of coordinates, it had crossed my mind on more than one occasion that the lathe compound slide was almost capable of being used as a general purpose radiusing tool. It has a swivel base and micrometer feed.

However, the tool is usually mounted quite a distance in front of the axis about which the compound slide rotates. This means that rotation of the compound slide would generate a fairly large concave profile.

Winding the compound slide rearwards as far as it would go brought the tool closer to the axis of rotation, but still in front of it, so the profile would remain concave. Another aspect of the cutting tip position is that it is usually offset from a line of travel passing through the centre of rotation.

Consequently, the relationship between compound slide position and radius of rotation at the cutting tip is not well defined. Furthermore, in the fully withdrawn position, the compound slide was not completely engaged with the dovetail on its base. To ensure rigidity, particularly in an application where the compound slide would be free enough to swivel, it would be preferable to have the dovetail fully engaged.

What was required was a toolholder capable of locating the cutting tip on a line through the centre of rotation of the topslide, and in such a location that the compound slide dovetail would be fully engaged for the generation of a reasonable range of radii.

With this objective in mind, I inspected the compound slide of my lathe more closely. It can be seen from Photo 2 that the Little John would never win a beauty contest against a Myford, but the simple shape and generous proportions of the compound slide casting were well suited to my objectives.

Photo 2. The LittleJohn topslide is not particularly attractive, but what it lacks in beauty is more than offset by its sturdiness and ease of modification. Good engineering doesn't have to "Look right" to be right.

I could see that using the compound slide for turning a radius was going to have disadvantages. In the first place, the physical bulk of the topslide would require the workpiece to overhang significantly from the chuck. Secondly, the angle through which the topslide could swing would be restricted by the presence of the chuck. At best, I would only be able to machine slightly beyond a hemisphere. Thirdly, machining beyond the hemisphere could be risky since I would be swinging the rear of the topslide towards the chuck while my attention would be on the workpiece. Provided I used a collet chuck, things would not be too bad.

Despite their several disadvantages my ideas had taken on a life of their own by this point. Heedless of their irrelevance, they were determined to be implemented. To make matters worse, my initial intention of having a plate with a block welded on for a toolholder, horrified them. My ideas made their disapproval known in no uncertain terms.

"*Methods like that are all very well for the mass produced market,*" they said. *"If you ever want to learn anything about precision engineering you'll need to smarten up your attitude."*

I tried to point out to my ideas that the job would take much longer if I didn't use welding. Furthermore, the welding set might feel slighted.

"We are an ideal opportunity for you to exercise care and strive to achieve the highest degree of precision," they insisted. *"We are every bit as important as any ball handles you might want to make with us!"*

My ideas continued… "*Absolutely everything that is done in this world derives its significance from the fact that somebody wants it to be done. The who and the why are entirely irrelevant.*"

My ideas brought their presentation to a conclusion as cogently as they had begun… "*To ignore us simply on account of the fact that we have no physical reality at present would fly in the face of Natural Justice. It is only by permitting ideas to experience substantive existence that Mankind has progressed from his stone-age lifestyle.*

Photo 3. With the paint removed it was evident that the topslide had been rough machined. Machine marks were cleaned by scraping. Note the reduced thickness of the slide in the central region visible at the end. The scribed line is parallel to the line of travel of the slide.

The case presented by my ideas was well founded, and irrefutable. Their desire to experience for themselves, an existence which was other than virtual was readily understood and evoked my sympathy. I was obliged to find in their favour.

A suitable toolholder would be required. This in turn meant that some means of securing the toolholder to the compound slide would also be needed. I chose to establish datum faces on the compound slide in order to achieve accuracy and repeatability when securing the radiusing toolholder. The central region of the compound slide is necessarily quite thin to accommodate its leadscrew as can be seen in Photo 3.

There is, however, a substantial amount of material along each side, and it was natural to position securing holes for the radiusing tool in these areas. My immediate requirement could have been satisfied by two or four threaded holes. In order to make provision for other accessories at some later date, I decided to machine the entire top surface and include a total of six securing holes. I had also been intending to fit a locking screw to the compound slide, so added this operation to my list of modifications.

The toolholder T slot is about 0.150" higher than the rest of the compound slide body. Scraping the paint off, revealed that the top of the body had been rough machined flat. The sides also appeared to have been machined. However, there was no reason to believe that the dovetail "V" would be parallel to either side. By moving the slide along its line of travel while holding it firmly against the dovetail, a line was scribed to serve as a datum parallel to the line of action.

The slide was mounted on the Bridgeport, with the scribed datum aligned to the cross feed axis of the mill table as illustrated in Photo 4.

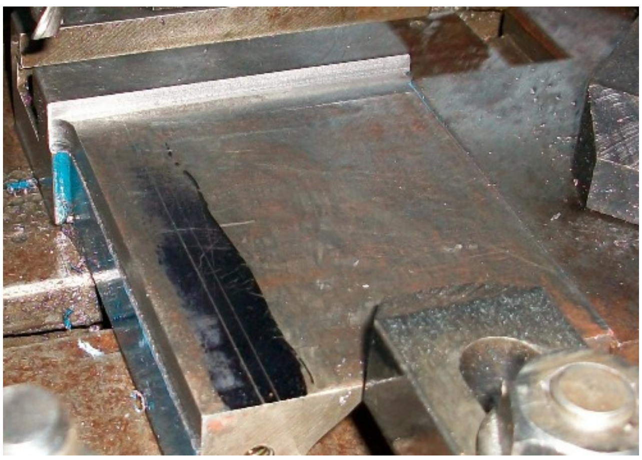

Photo 4. The slide was mounted with the scribed line parallel to the milling table cross feed. Datum faces were machined along the left hand edge of the slide and to the rear of the T slot.

A reference face was machined along the edge of the slide and the rear face of the T slot was also machined to provide an orthogonal datum face. The securing holes were then drilled and tapped prior to surface grinding.

I am aware that some individuals are reluctant to make modifications to their machine tools and tooling. One justification for such reticence may be the perception that the "*Collectors' value*" of the machine could be adversely affected. Owning or maintaining possessions on the basis of some supposed value others might place on them at an ill defined point in the future seems to me to be rather pointless. The value of a machine is in its ability to perform a useful function. Had the original designer of my machines been faced with similar requirements to my own, then any of my modifications might well have been incorporated from the outset.

The absence of a modification I require is not a rational reason for retaining the status quo. The only sound engineering reason for deciding against a modification is that the equipment will be degraded by the proposed alteration.

The toolholder itself would be in two parts. The first would be the toolholder block. This block was drilled to hold a cutting tool made from 1/4" diameter high speed steel (HSS). The hole for the cutting tool slopes downwards towards the rear at 17°. This is the same angle as that used by Jones and Shipman in their HSS toolholders. The top rake provided by this angle is appropriate for machining mild steel, which is the most common material for my purposes. The angle also provided a reasonable degree of height adjustment without having a serious effect on the tool overhang. The front face and top of the block were machined to correspond to the angle of the tool. Photo 5 shows the shaper being used to surface grind the side face of the toolholder block.

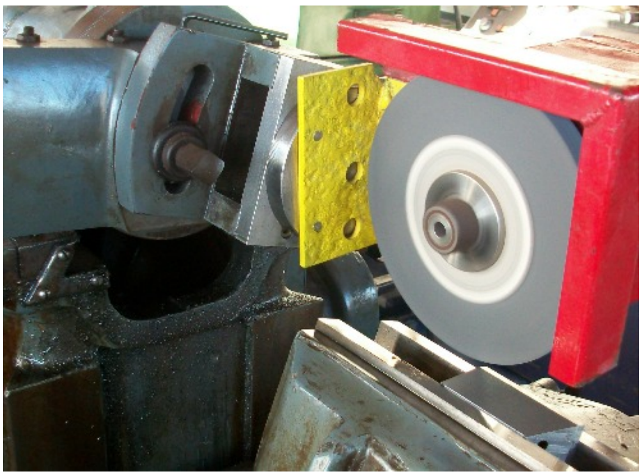

Photo 5. The head on the shaper is rotated to within about 5 degrees of horizontal, providing sensitive height adjustment during grinding operations.

The toolholder block is secured to a baseplate which has appropriate holes and datum faces to match the compound slide. Photo 5 shows the underside of the plate.

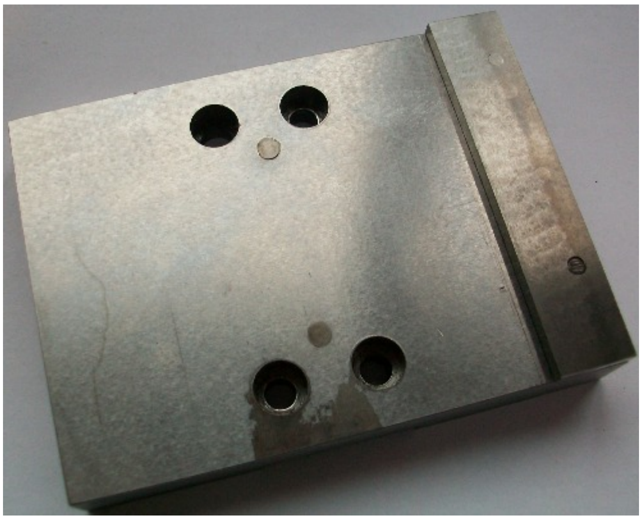

Photo 6. The mounting plate prior to drilling the holes for securing to the compound slide. Dowels for the toolholder block and the datum strip are visible.

The strip on the right hand side was dowelled and secured in position by setscrews. Fitting was subsequently carried out by grinding the strip along its edge. This ensured that the centreline of the cutting tool intersected the axis of rotation of the compound slide. The setup employed is shown in Photo 7.

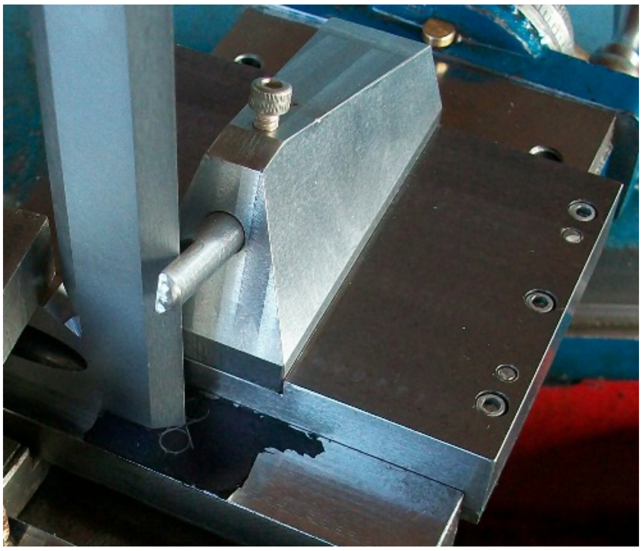

Photo 7. The try square was aligned with the axis of rotation of the compound slide. Clearance between the gauge rod held in the toolholder and the edge of the try square was measured. The datum strip secured along the side of the baseplate had a machining allowance from which the appropriate amount was removed by grinding.

Once the datum strip had been correctly fitted, securing holes were drilled and counterbored in the baseplate to align with those already drilled and tapped in the Compound Slide.

Photo 8 illustrates the finished tool having turned a small diameter ball end on a piece of rod. The excessive overhang of the rod was a consequence of holding the work in the 3 jaw chuck.

Photo 8. The spherical turning tool having machined a ball end on a test piece. Note the excessive overhang of the work.

Despite their limitations, my ideas declared that Justice had not only been done but had been seen to be done. They also expressed their unequivocal delight and gratitude for having been granted physical existence.

J W Cahill

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