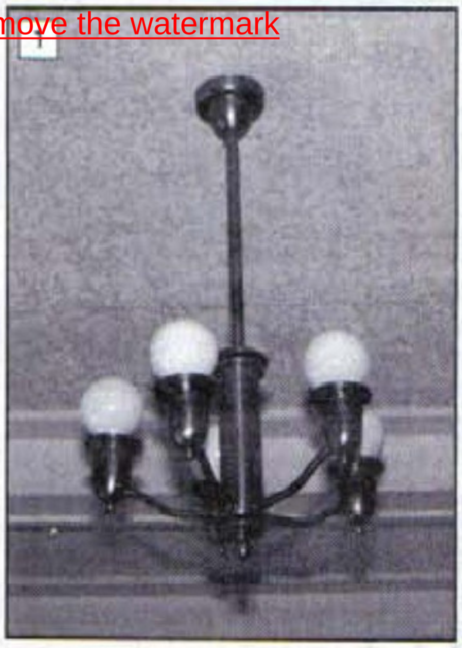
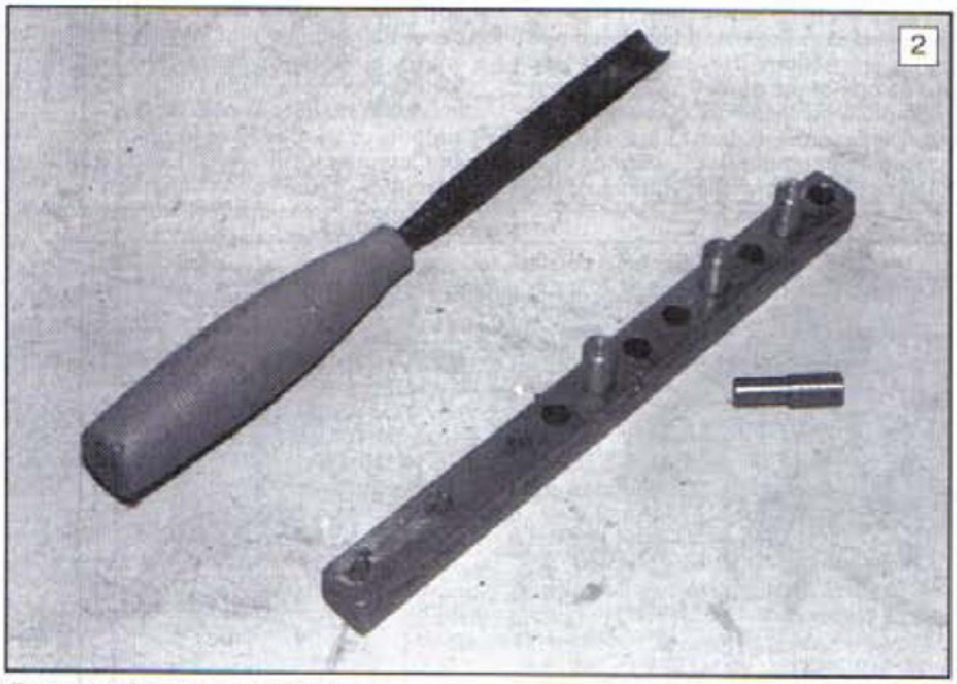
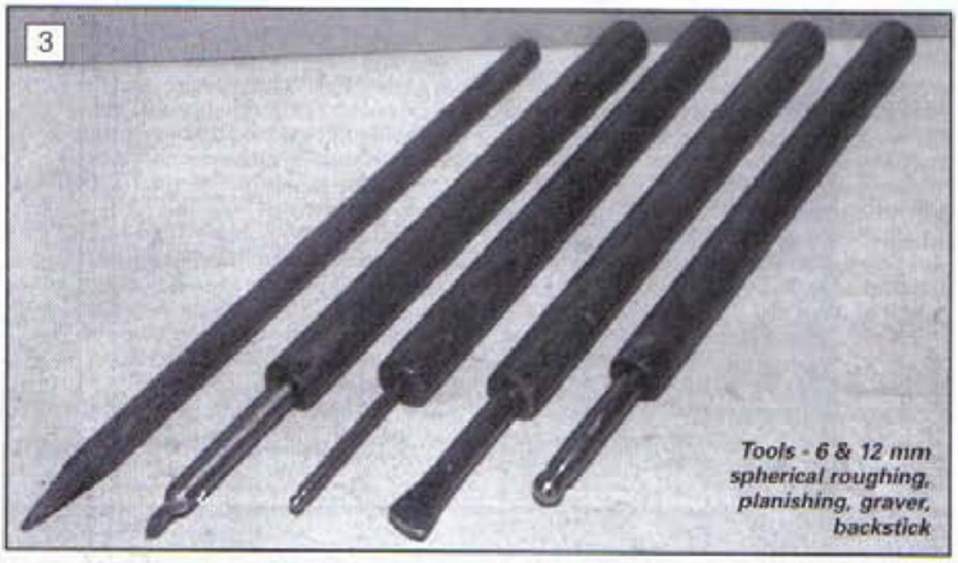
METAL SPINNING FOR THE BEGINNER

Australian contributor, Philip Amos decided to learn the techniques of metal spinning. He started by searching for any literature on the subject, then investigated the theory. His subsequent practical experiences are recounted here.





Tool rest with pins; wood gouge



Tools - 6 & 12 mm spherical roughing, planishing, graver, backstick

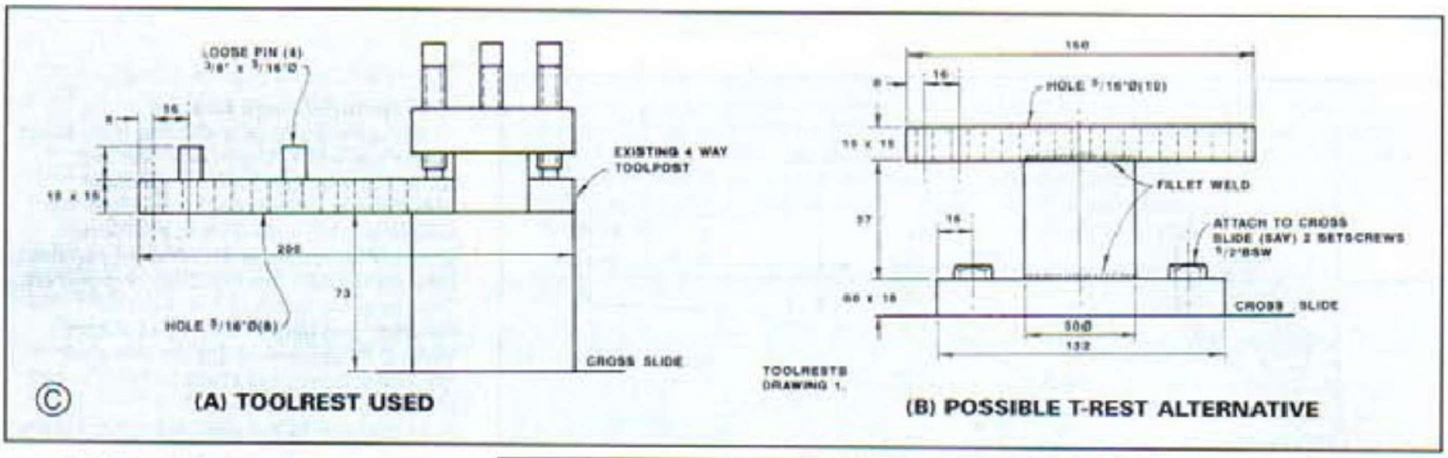
Very few model engineers would have access to deep drawing press facilities, and even if they did, they would seldom find it worthwhile to make up the necessary punches and dies to produce a few long, hollow sheet metal objects for some project. If the depth of the job is not too great - say half its diameter, then the traditional sheet metal techniques - hollowing, raising, or sinking (see reference 4) - can be used. These are slow and tedious.

Thus in commercial workshops, as well as in model work, the fairly ancient practice of metal spinning is adopted. In essence, this involves rotating a disk of metal in a lathe at high speed, and forcing it over a former, by pressure from a hand held, smooth, hard steel tool, levering about a pivot on a slide rest.

Recently I had a need for some sheet metal brass cup shaped pieces, to make light fittings to match others in our house, which are about 75 years old **(Photo 1)**, and thus had to develop the metal spinning skill. I consulted all the books in my workshop library, and found some information in references 1 to 5. Later, I remembered something some years back in *M.E.W.*, and identified reference 9. With the aid of Lautard's index of *M.E.* from 1920 to 1988, my own copies of *M.E.* from 1988 to 1996, and references found in some of the *M.E.* articles I looked up covering 1898 to 1920 in the NSW State Library, I identified some 12 items in *M.E.* on metal spinning. Some of these were merely queries, some irrelevant and some quite superficial. However several were very informative, and are listed as references 10 to 13. I also found some books on metal spinning in the State Library, but these were of limited help. No doubt there are other general books on sheet metal work, with information on spinning, but I was not able to search this out.

Almost all the references warn of various problems, pitfalls and difficulties, but do not give many suggestions about avoiding these, or dealing with them when they are encountered. More or less "have a go and you'll learn by experience".

I had started my project using the Wakeford (Ref. 4) information, which was



© **(A) TOOLREST USED** TOOLRESTS DRAWING 1. **(B) POSSIBLE T-REST ALTERNATIVE**

most helpful, and later progressed it with assistance from the Jeeves article (Ref. 9, also of great help). However, I found myself in various difficulties, and so set out on the Library search and some contemplation of what was actually happening in the workshop.

Authors such as Wakeford, Jeeves and Lammas (Ref. 13) are obviously expert in this field, although their articles are somewhat generalised. I hope this present one is sufficiently specific to address all the problems I encountered, and how I learnt to avoid some and correct others.

Safety

With a piece of sheet metal whirling around at high speed in the lathe, a careful approach is essential. A leather apron is desirable. Safety glasses or goggles, or a face mask, is essential. I am ambivalent about leather gloves - I just don't like gloves near rotating machinery, so I don't use them.

Equipment

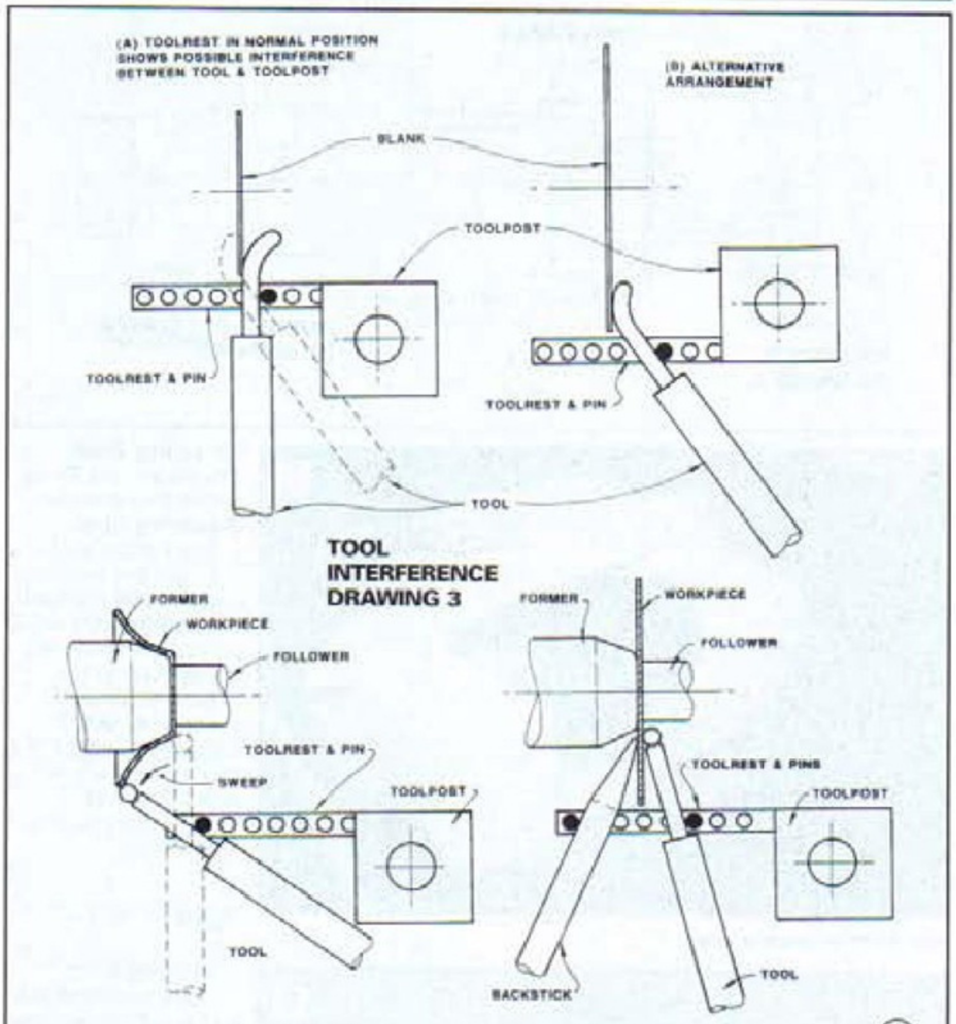
A lathe with strong headstock bearings is needed, and with a reasonable amount of power. Mine is 6in. centre height, with taper roller bearings in the headstock and a 1hp motor. Speeds suggested in the references are 1300 rpm for aluminium alloys, 1000 rpm for brass and copper, and 700 rpm for steel. A rotating tailstock centre is also needed. If necessary this can be home-made (Refs. 4,9,10).

Tool Rest

The pivot support for the tool can be a simple length of steel bar, with holes and pins, fitted in the lathe toolpost as indicated in Ref. 13, which I adopted, or it can be a special T-rest, similarly with holes and pins, which replaces the complete lathe topslide (Refs. 4 and 9).

The pins should be shouldered to fit the holes in the bar without dropping through, and their height above the bar should be at least equal to the maximum diameter of the tools used. In my case the bar is 15mm x 15mm x 200mm; the 8 holes are $^5/_{16}$in. diameter spaced at $^5/_8$in. The pins are $^3/_8$in., reduced to $^5/_{16}$in. diameter, and project $^5/_8$in. above the bar. I made four pins, but usually only two are required. **(Drawing I(a) and Photo 2).**

If the items to be made are relatively small, this bar-in-the-toolpost arrangement is quite satisfactory, but if

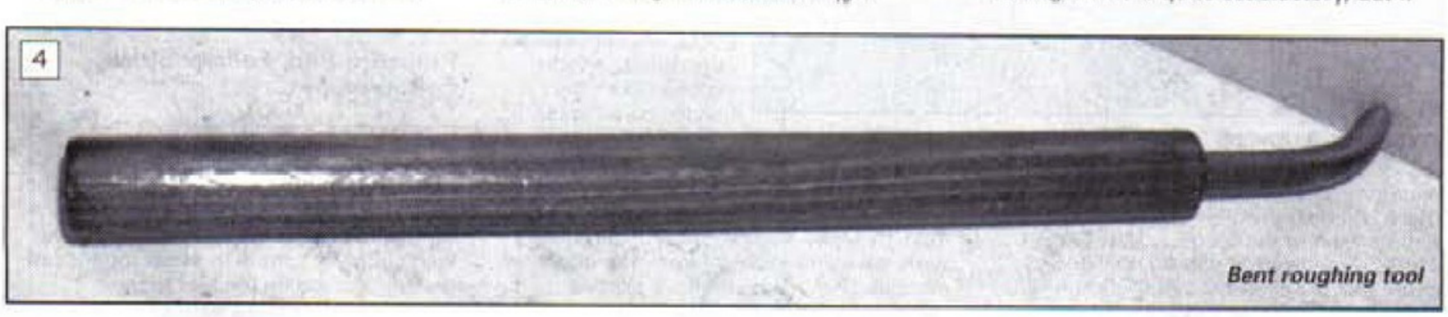


TOOL INTERFERENCE DRAWING 3

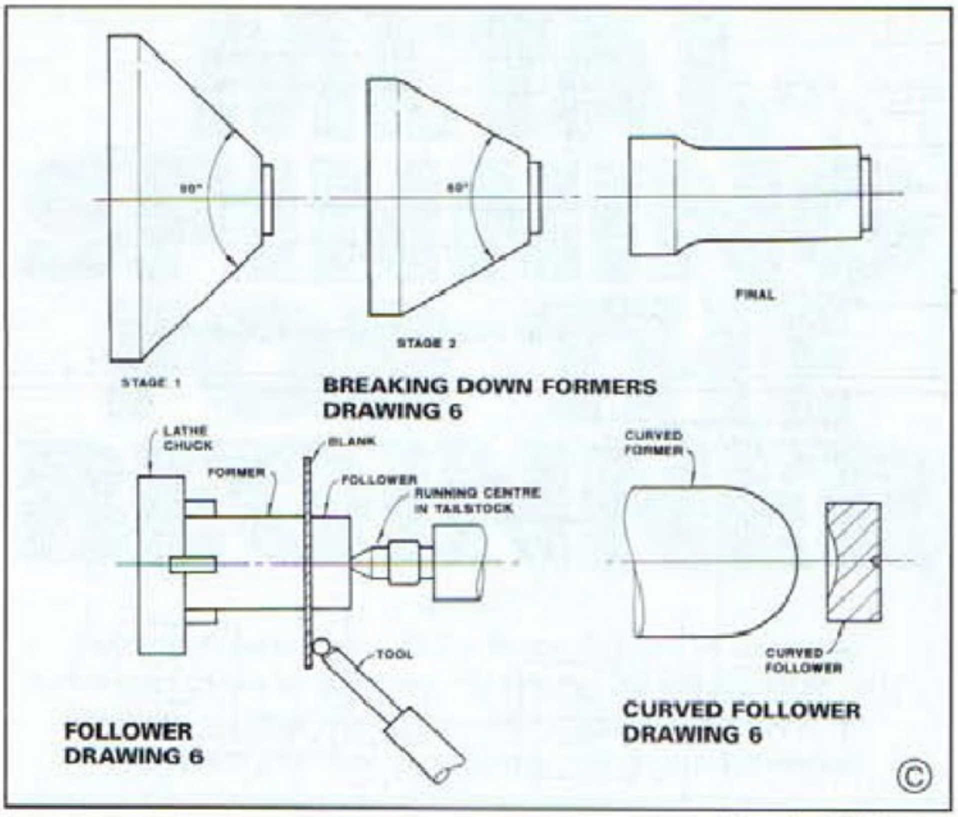
TOOL SWEEP DRAWING 3

USE OF BACKSTICK DRAWING 4 ©

4



Bent roughing tool



Fire brick annealing cave

Blank after hollowing

wider sweeps of the tool are necessary, there can be a problem of the tool or handle fouling the toolpost **(Drawing 2(a))**. Sometimes, it will be possible to avoid this problem by mounting the tool rest on the operator's side of the toolpost **(Drawing 2(b))**. Otherwise, the T-rest would be preferred **(Drawing I(b))**.

The height of the tool rest bar should be such that the tool can comfortably work on the centreline of the former, or be angled down somewhat. Ref. 11 suggests applying the tool to the work at about 7 o'clock looking towards the headstock.

Tools

a) Length

The recommended tool length varies from 12in. with a 24in. handle (Refs. 3 and 9), to conversion of an old chisel, 6in. with 6in. handle (Ref. 2). What is needed is the ability to pivot the side of the tool on the pin in the rest, and sweep the whole of the blank **(Drawing 3)**. Thus the blank radius plus about 1in. might be an appropriate length exposed from the handle. If you want to operate the tools in the traditional fashion, with the handle under your right armpit, it will probably require a handle length of 18in. to 24in.—say overall 36 inches. My tools have 3in. exposed from 1in. diameter handles 12in. long, and have proved satisfactory for my project.

b) Materials and Shapes

My spinning tools are made from silver steel - one each of $\frac{1}{4}$in. and $\frac{1}{2}$in. dia., turned to a ball end with a spherical turning attachment, and two of $\frac{1}{2}$in. dia. forged to a bent shape and a flattened shape **(Photos. 3 & 4)**. All were polished, then hardened right out, then re-polished. The tools are inserted 2in. into the handles, and held in with epoxy resin. Various references suggest bronze or hardwood tools, but I doubt their efficiency.

In addition to the spinning tools, I made a graver by grinding a piece of 5mm square high speed steel at a 45deg. angle across one corner, and silver-soldering this into a hole in the end of a piece of $\frac{1}{2}$in. diameter mild steel — again exposed 3in. from a 12in. handle. A backstick was made from a piece of $\frac{3}{4}$in. diameter wooden dowel by cutting it to a 2in. long wedge shape at one end. Its use is shown in **Drawing 4**.

Formers, Mandrels and Chucks

These terms are interchangeably used by different authors. If many items are to be made to the one pattern, it may be best to make the former from mild steel, with a polished finish. Its dimensions and shape should correspond to the inside of the required finished article. However, for general work hardwood seems to be perfectly adequate.

Depending on the shape, the former may be made with its own chucking piece incorporated, to allow it to be held in the 3 jaw lathe chuck. Alternatively, it may be arranged to attach to a separate chucking piece. I have used both practices for various items of my project.

References 5 and 9 draw attention to the use of one or more 'breaking down' formers, as part-way operations towards production of a deep article. **Drawing 5** shows this concept. In my case, I used one 60deg conical breakdown former towards the making of the cup shaped articles, as suggested in Ref. 9.

Refs. 2,4,5,9 & 10 mention the use of formers which can be dismantled into a number of pieces, to remove from a finished part which is smaller at the 'mouth' than towards its closed end. I have not tried this technique, but it seems self evidently practicable.

Later I shall discuss removing work from a normal former, which is not always easy to do, but there are some things which can be done to facilitate later removal. When it is acceptable to the design, shoulders on the former should be generously radiused and cylindrical parts might have some draft (as for casting).

Pressure Pad, Follow Block, Follower

Again, these terms are used interchangeably by different authors. Its function is to hold the blank firmly against the end of the former, so that the blank is both held in axial alignment and rotated with sufficient torque to offset the friction loading applied by the tool to the workpiece. **(Drawing 6)**.

In the simplest case, where the end of the former is a flat, perpendicular to the lathe axis, the follower is similarly flat. If there can be no hole in the workpiece, then the follower must exert sufficient pressure on the work against the former, so that friction drive can rotate it. Some authors suggest the use of a piece of emery cloth between the former and blank to enhance this drive.

A blank with no centre hole should be roughly centralised axially between former and follower, with minimal pressure applied to the latter. With the lathe rotating very slowly, a piece of wood applied radially to the blank can be used to centralise it. Full pressure must be applied to the follower before the lathe is run at full speed for the spinning operation.

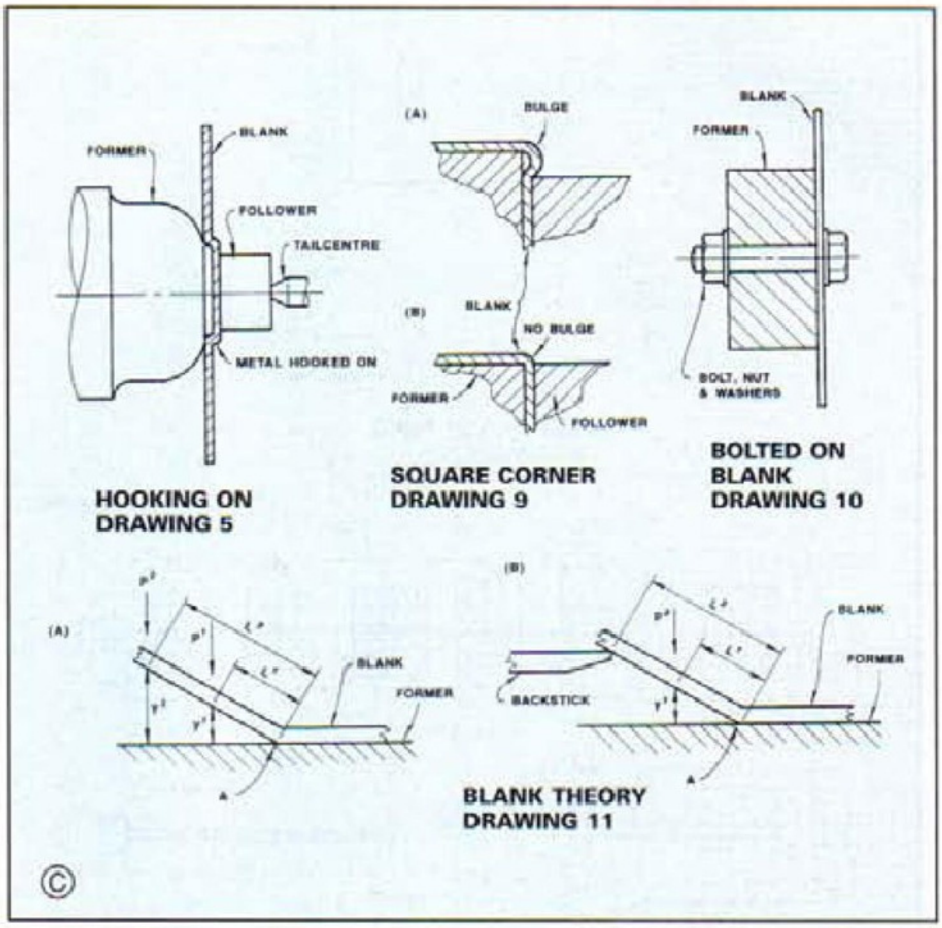
When there is no axial hole in the blank, there is sometimes a step in the former, and when this is enveloped by the blank it is said to be 'hooked on'. This prevents radial movement from then onwards **(Drawing 8)**.

If the end of the former is curved e.g. hemispherical, then the follower must be similarly hollowed out to match the curvature **(Drawing 7)**.

Some authors suggest using just the running centre pressed directly against the blank, but I have had no success when trying this. I have used a small diameter steel follower, centred on one side, and with an axial rod on the other to engage a hole in the blank and in the former, to ensure a positive drive to the blank. I have also used with this, an internal/external star washer between follower and blank. This has proved very effective, although it leaves tooth marks on the blank. Once sufficient blank material has been moved along the former to produce adequate friction to rotate the blank against the load of the tool, then the star washer is no longer needed and may be removed.

If a dead square corner is being attempted around the end of the former, then the diameter of the follower must be the same as that of the former, otherwise bulging on the end is likely to result **(Drawing 9)**.

Where a substantial hole in the job can be tolerated, the follower can be dispensed with if the blank can be through bolted on to the former. It is preferable still to put a centre hole in the bolt head and to use this with the tailstock running centre for support for greater stability and to avoid



HOOKING ON DRAWING 5

SQUARE CORNER DRAWING 9

BOLTED ON BLANK DRAWING 10

BLANK THEORY DRAWING 11

Cup Shape Statistics — Surface Area = 13616 = 'A'

Blank No	Blank Diameter	Blank Area	Cut Off Dimensions Thick.	OD	ID	Width	Area	Final Net Area	% Less Than 'A'	Remarks
1.	180	25457	(i) 1·25	180	155	14	7370			Periphery Method.
			(ii) 1·15	149	130	11	4823			
			(iii) 1·05	128	108	14	5192			
			(iv) 0·85	95	71	19·5	5087			
					Total		22472	2985	78	
2.	132	13690	(i) 0·85	131	100	18	6534			Equal Areas Method.
			(ii) 1·00	103	80	18	5176			
					Total		11710	1980	85	
3.	110	9507	0·75	105	70	23·5	6463	3044	78	Earlier Experience Method.
*4.	100	7857	0·90	76	70	11	2524	5333	61	
5.	100	7857	0·93	75	70	9·5	2165	5692	58	
6.	100	7857	1·05	74	70	5	1131	6726	51	
7.	100	7857	NIL					7857	42	

* 2nd attempt – 1st cracked: see photo

DRAWING 13

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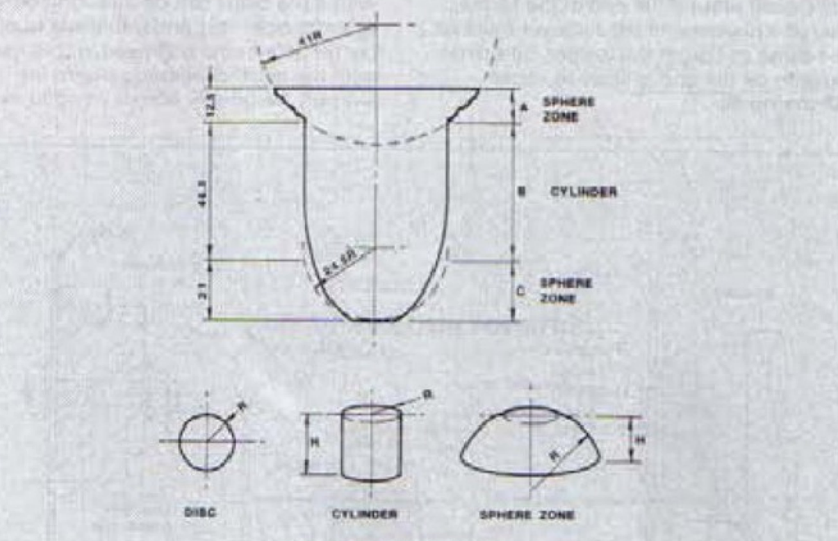
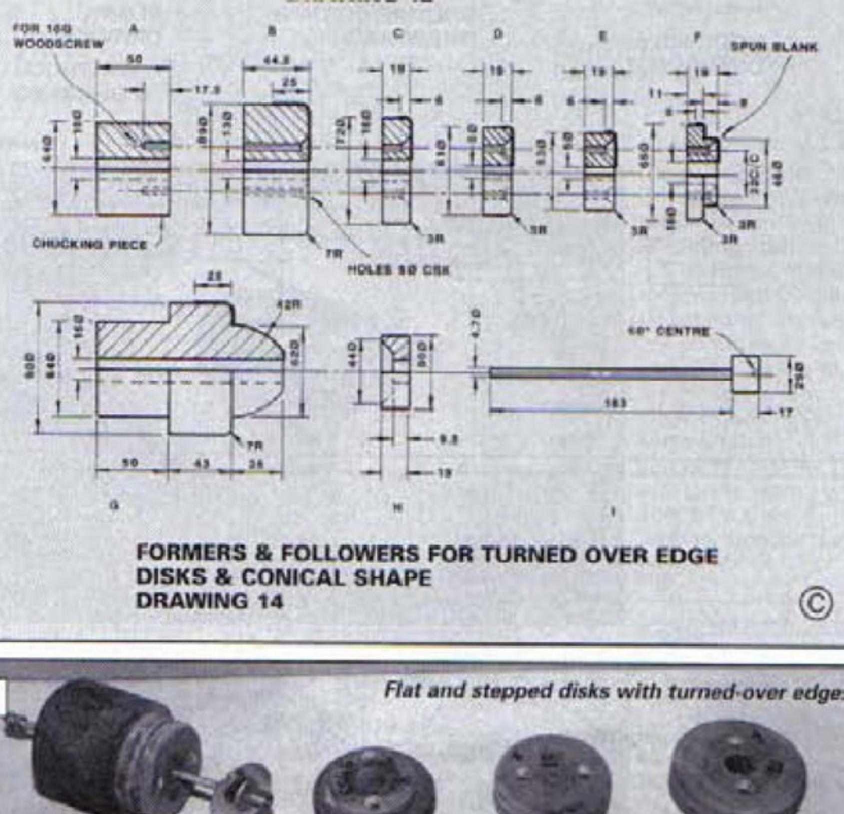


CUP BLANK AREA
DRAWING 12

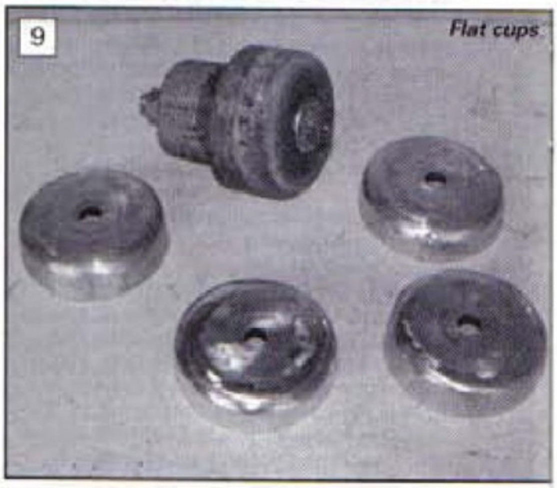


FORMERS & FOLLOWERS FOR TURNED OVER EDGE DISKS & CONICAL SHAPE
DRAWING 14

7 *Flat and stepped disks with turned-over edges*

Conical shape

8



9 *Flat cups*

undue strain on the headstock **(Drawing 10)**.

Theory

To take up a new form, the material must plastically deform; it must be stressed to exceed the elastic limit or it will merely spring back. That is it must exceed the yield point for steel or the proportional limit for non-ferrous metals. For those who would like to understand some of the theory behind this, Appendix I contains the necessary calculations.

What are we to deduce from all this figuring?

I. It is important to progressively make the blank lay along the former from the centre outwards, in order to reduce the length we are trying to deflect.

II. The backstick magnifies the deforming force applied to the blank where it contacts the former.

III. The outer part of the blank is best kept radial as the work progresses, in order to allow access for the backstick for as long as possible.

Blank size

The maximum disk OD is limited by the centre height over the lathe bed, but also by the need to be able to position the tool pivot support in a suitable location. This latter requirement will be affected by the distance towards the operator that the cross slide can be retracted.

Most of the references warn against excess diameter for the blank, as any unnecessary metal hinders the movement of the material and also leads to crinkles and ripples in the workpiece, reverse bending (curling at the edge) and edge cracking.

As a starting point for determination of the blank diameter, various of the references suggest using the axial periphery of the finished workpiece, measured for example by a piece of soft copper wire bent axially around the former and then straightened out for measurement. For deep workpieces, this yields a value much too high - refer to the example below.

Ref. 7 mentions the theories of Equal Volumes and Equal Areas. It is self evident that the volume of the material of the job at the finish must be equal to the volume of the blank at the start. In the home workshop situation, it is hardly possible to assess accurately the degree to which the thickness of the material will be increased (unlikely) or decreased, so for this present exercise, it is assumed constant. For this assumption, the surface area of the finished job will equal that of the blank at the start. As will be shown below, the action of working the metal down to conform to the shape of the former does, at the same time, significantly reduce its thickness.

Consider the cup shaped example in **Drawing 12**, which is to be spun in 1.2mm (18 SWG) brass. To calculate the finished job surface area will require some approximations - it can be thought of as two pieces of spheres joined by a cylinder. Useful area formulae from Ref. 14 are -

Disk	πr^2
Cylinder	$2\pi rh$ (for curved surface)
Spherical Zone	$2\pi rh$ (for curved surface)

For the example -

Part a (zone) $2\pi rh = 2 \times {}^{22}/_{7} \times 41 \times 12.5 = 3221$

Part b (cylinder) $2\pi rh = 2 \times {}^{22}/_{7} \times 24.5 \times 46.5 = 7161$

Part c (zone) $2\pi rh = 2 \times {}^{22}/_{7} \times 24.5 \times 21 = 3234$

Total A = 13616

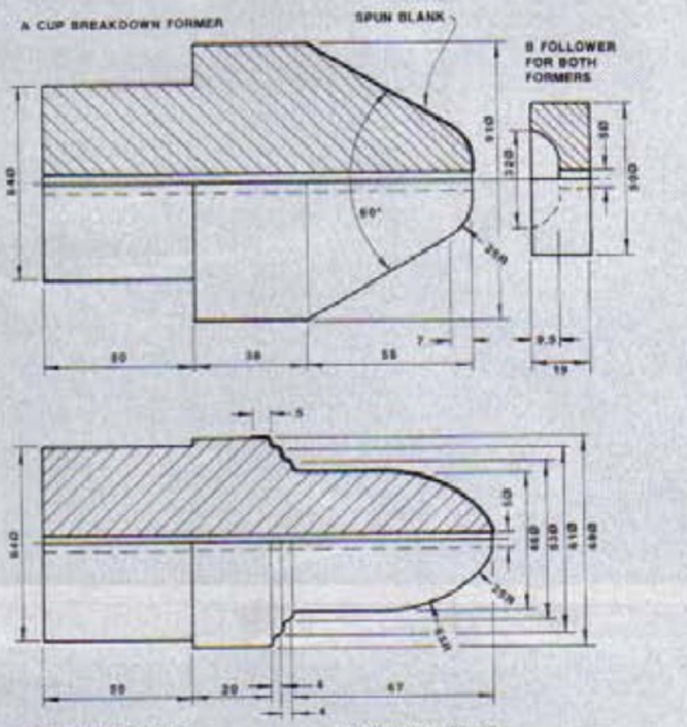
The equivalent area of a disk = πr^2

Thus $r = \sqrt{(13616/\pi)} = 66$

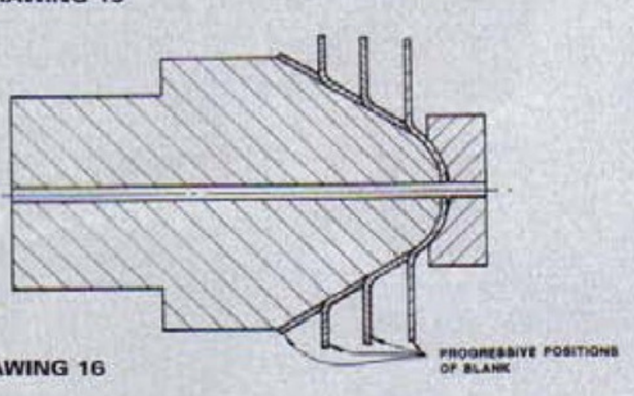
Using a copper wire to measure the periphery p = 96. This yields a disk diameter = 96 x 2 = 192, for which the area = 28965. This is more than double the total area A arrived at above.

On the actual job, I started with 180mm diameter, and in the course of the operation sawed off, in turn, annular rings of dimensions as shown in the tabulation (including the final trimming operation) - all curved in section. The areas of these rings are computed as mean diameter times width by π. The results are tabulated in **Drawing 13**. The tabulation shows that the pieces cut off form a significant part of the total blank, and the final job area has only been achieved by considerable thinning taking place.

Nevertheless, in my view the equal areas method recommends itself as the way to go. If there is only one item to make, then the use of the equal areas method will ensure that at least there is sufficient material in the blank to do the job, but probably some will have to be trimmed off at the finish to bring the job to size. However if several items of the same pattern are to be made, it is possible to try progressively smaller blank diameters, each depending on the experience with the previous size. In my case I needed seven of these cup shapes. My first try, using the axial periphery method, yielded a blank diameter of 192mm, but I decided that 180mm would probably be more than sufficient, and so it transpired! The next one tried was 132mm diameter from the equal areas method, which also proved excessive. The third was 110mm, and the remaining four were all 100mm. These results are included in the tabulation, to



DRAWING 15



DRAWING 16

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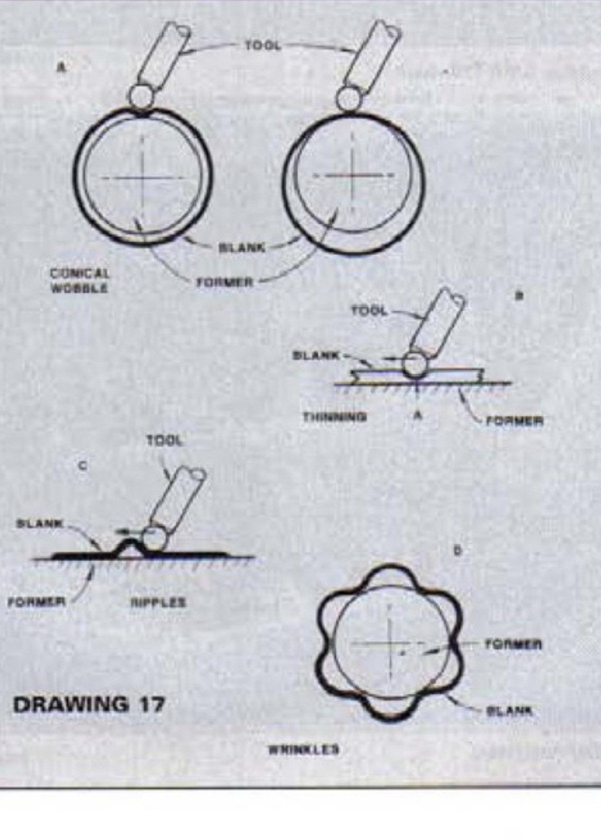

DRAWING 17

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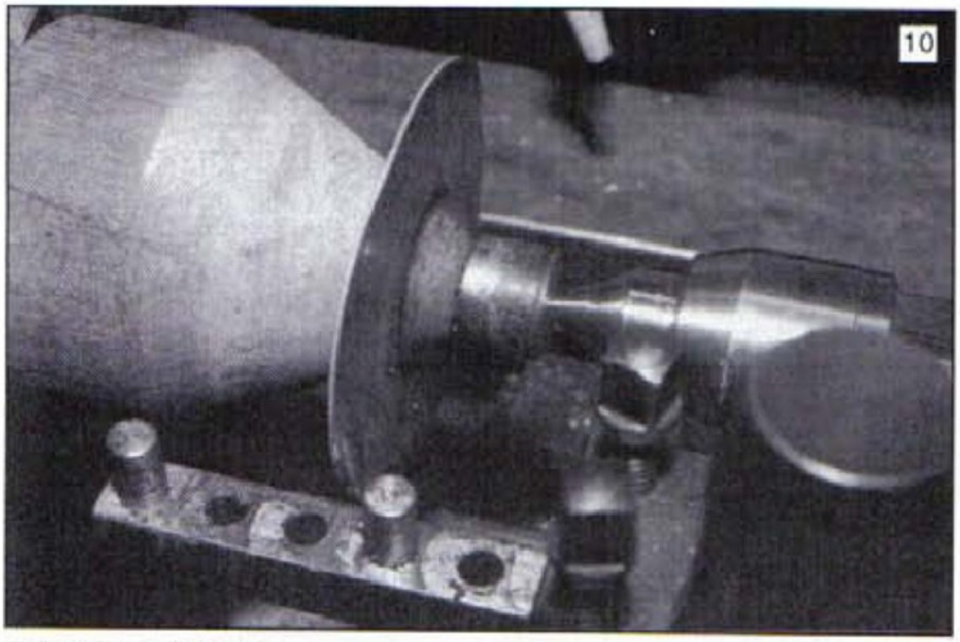
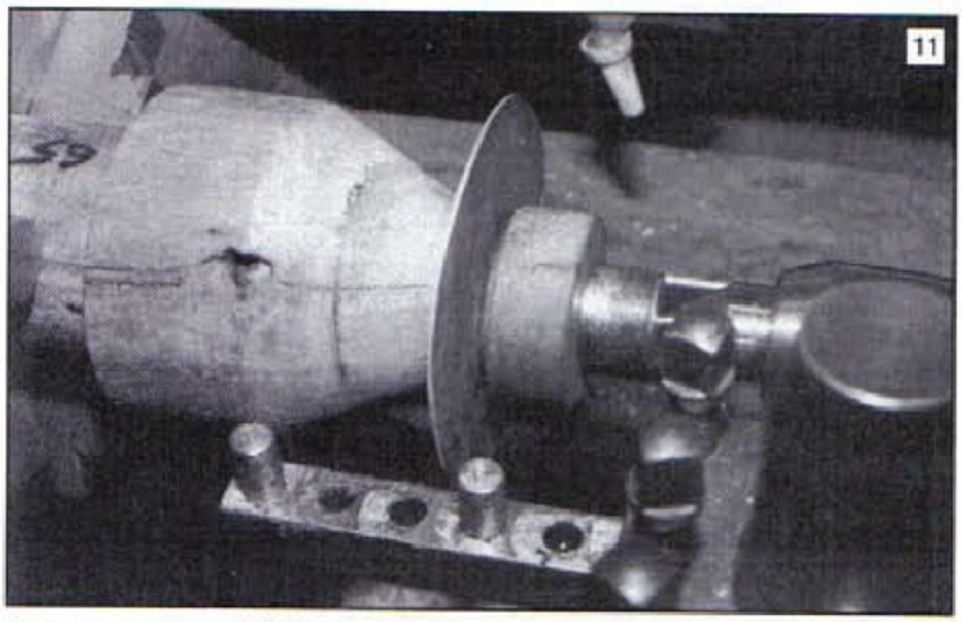
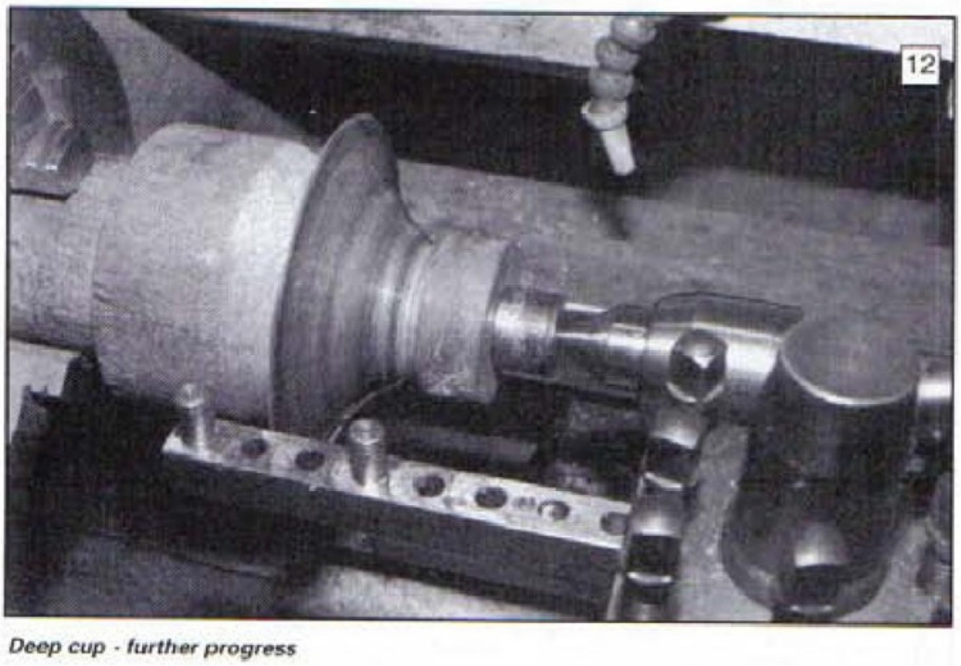

Deep cup - blank at start


Deep cup - progress with follower


Deep cup - further progress

demonstrate the point. Clearly there has been a great reduction in thickness for these reduced diameter blanks to be worked out to form the final job shape, although the measured thicknesses of the cut off pieces cannot accurately reflect the true thickness of the remaining part of the blank.

The seventh item was made from a blank from a different sheet of raw material, and although worked and annealed the same way as the others, it did not stretch as much, and only just made it to the final axial dimension. Thus it is suggested, to avoid disappointments, only use diameter reduction experience for material coming from the same sheet. Regard material from a new sheet as starting again —in this case, I would revert to the equal areas 132mm diameter.

Material Thickness

Various references suggest a useful range of material thicknesses from 1.6mm (16 SWG) to 0.5mm (26 SWG). Metal thinner than 0.5mm seems to tear easily. From my experience with 1.2mm (18 SWG) brass, I would suggest that the thickest used be 0.9mm (20 SWG), as it is very difficult to make the thicker material flow when a deep job is being made, despite frequent annealing.

Annealing

For successful spinning, the material must be in a soft state. Brass, copper, aluminium alloys and steel undergo work hardening to a greater or lesser extent, so it becomes necessary to frequently anneal the material for the spinning process to continue. Ref. 2 states "in no time at all, the disk will refuse to play - so knock off and re-soften". While it may be tiresome to have to continually dismantle the workpiece from the former and carry out the annealing, it is an essential part of the spinning process.

Brass, copper and aluminium alloys can be annealed by bringing to dull red heat, then plunging into water. Some references suggest delaying the quenching until the piece is no longer red. Because the actual rate of cooling is not important, it is not necessary to have the whole of a large workpiece red at the same time - sometimes difficult to achieve - as long as each section has reached red heat, all should be well. Steel must be heated bright red and allowed to cool slowly e.g. overnight in the furnace after it has been turned off, or in the ashes of a fire. This obviously prolongs the overall spinning process immensely.

In my case, I made up a small cave of fire bricks **(Photo 5)** -and used a Primus LPG torch with its largest nozzle. I also had a laboratory methylated spirit lamp as a pilot flame for convenience, and used a pair of Multigrip pliers to pop the workpiece in the water tank (an old baking dish).

Typical annealing times for the 1.2mm brass items were 1 to 3 minutes depending somewhat on the shape of the job at that stage, and also on how hot the fire brick cave was. $1\frac{1}{2}$ min. would be the most common for the annealing heat and quench process.

For the cup shaped job described in this article, the time taken for each phase of the operation was of the following order :-

Phase	Operation	Av. No. of Annealings	Av. Elapsed Time for Phase (min.)
I	Hammer hollowing blank centre for follower	5	15
II	Spinning on breakdown conical former	13	70
III	Spinning to finished shape	77	17
		35	162

With the most common annealing time of 1½ min., annealing took about 53 min. in a total of 162, or about ⅓rd, to compare with ⅔rds working the metal.

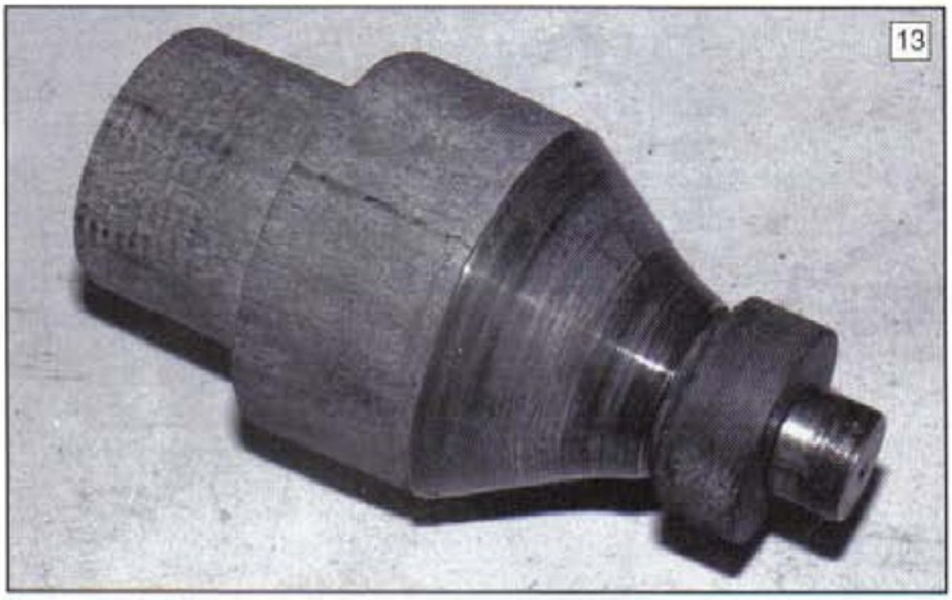
As it is hard to judge the temperature of aluminium alloys which can easily go from normal cold appearance straight to melting collapse, Ref. 4 suggests rubbing bar soap on the aluminium and heating it until the soap goes black—then allowing it to cool. Ref. 5 suggests using a smoky oxy-acetylene flame to cover the workpiece with soot, and then to heat it until the soot burns off. After cooling it is claimed it will then be dead soft. Note that aluminium alloys age harden, so if it is not proposed to continue work on the softened piece at once, it should be placed in the family freezer, which will delay the age hardening process.

Lubricants

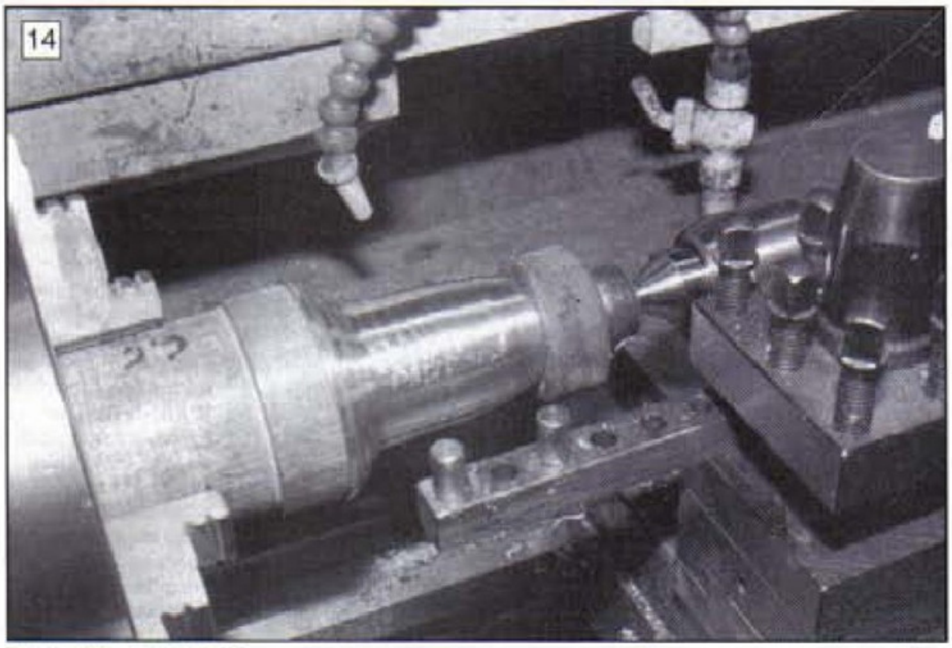
To stop the tool tearing the workpiece, a lubricant must be used. Various references suggest tallow, grease, beeswax, soft soap, laundry bar soap etc. I have tried grease, but found that it was flung around excessively, and so eventually settled on bar soap, which seems quite satisfactory.

Technique

For my project, I needed five items in 0.5mm (26 SWG) brass, and eleven items in 1.2mm (18 SWG) brass. For the 0.5 mm items, three were flat disks with a turned over lip, one was a stepped flat with lip, and one was a rather fancy conical shape **(Drawing 14 and Photos. 7 and 8)**. The only one with a critical dimension was the stepped flat disk, where the step had to fit reasonably closely inside a brass tube on assembly. For the 1.2mm items, four were shallow flat cups, with generously rounded corners **(Drawing 14 and Photo. 9)**. The other seven were deep conical cups **(Drawing 15 and Photo. 15)**. I made hardwood formers for the various disks, interchangeably mounted with two wood screws on a cylindrical hardwood chucking piece, and each was finish machined, in turn, in place on this mounting cylinder. Likewise hardwood formers were made for


13

Deep cup - breakdown completed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Deep cup - completion


15

All seven deep cups

16 *Cracked deep cup*

17 *Three branch light*

the cup shapes, including a breaking down former for the deep cup - these mostly included their own integral chucking pieces. Cardboard templates were used to check shapes, and normal wood turning methods used mainly with the gouge shown in **Photo. 2**. Some items were to have centre holes $\frac{5}{8}$in. dia., some $\frac{1}{2}$in. dia., and others $\frac{3}{16}$in. diameter. Suitable length clamping bolts were used for the $\frac{5}{8}$in. and $\frac{1}{2}$in. hole items, to hold the followers in place, each bolt having its head centre drilled to accept the running centre support. In the case of the $\frac{3}{16}$in. holes, such an arrangement was too weak, so instead, a piece of $\frac{3}{16}$in. steel rod was silver-soldered into a boss $\frac{5}{8}$in. long and 1in. dia., the end of which was also centre drilled. This was held in place by the running centre, and proved quite satisfactory **(Drawing 14 item I)**. For the cup shaped jobs, the first phase was to hollow the centre of the blank disk using a 22oz. ball pein hammer and the follower as a 'doming block' **(Photo. 6)**. The follower soon split, so was PVA glued together and supported with a hose clamp tightened on its periphery. After hollowing, the disk would then fit the former and follower, with further shaping by spinning. Phase two was spinning the blank to the shape of the breakdown former, and phase three, spinning to the final finished shape.

Photos. 10 to 15 show this sequence. In the actual spinning operation, the tool is used in lever fashion, with the tool rest pivot as a fulcrum, and is swept from the tailstock end and centre of the disk towards the headstock end and outer edge of the disk in a continuous motion. It thus applies pressure to the workpiece in both axial and radial directions. Most authors recommend this action, but some warn that it will lead to "folds that are almost impossible to remove" and "always start to exert the tool pressure from the outer edge of the disk" (Ref. 1). In my experience, this is quite wrong. It is essential to progressively make the blank enfold the former from the tailstock end, as shown in **Drawing 16**. However, at all times during this progression the 'sweep' of the tool must run to the outer edge of the disk, and with the use of the backstick for as long as that can be accommodated, if ripples and wrinkles are to be avoided. What we are trying to do is to locally distort the blank to reduce its diameter, as shown in **Drawing 17(a)**. If the blank is not firmly in contact with the former at the tailstock end, the whole blank can wobble, as shown in the drawing, and nothing is achieved. When the final shape is achieved, and the workpiece closely envelops the former, it is often difficult to remove. Reference 12 suggests running the lathe with no follower in place, and using a flat tool under the work and over the tool rest, to exert pressure and ease the work away from the chuck end. When the work comes loose, stop the lathe.

Trimming

When the workpiece has finally reached the desired shape of the former, it will usually have an uneven edge. If the required axial dimension is not overly critical, this edge can be trimmed by hand use of the graver, supported on the tool rest. More precision can be obtained by using instead a normal pointed lathe tool (e.g. 60deg. threading tool) mounted in the normal tool post on the top slide and cross slide. A parting off tool should not be used, as this will tend to tear the material and can destroy the workpiece.

Problems

These may be categorised as cracks, ripples and wrinkles.

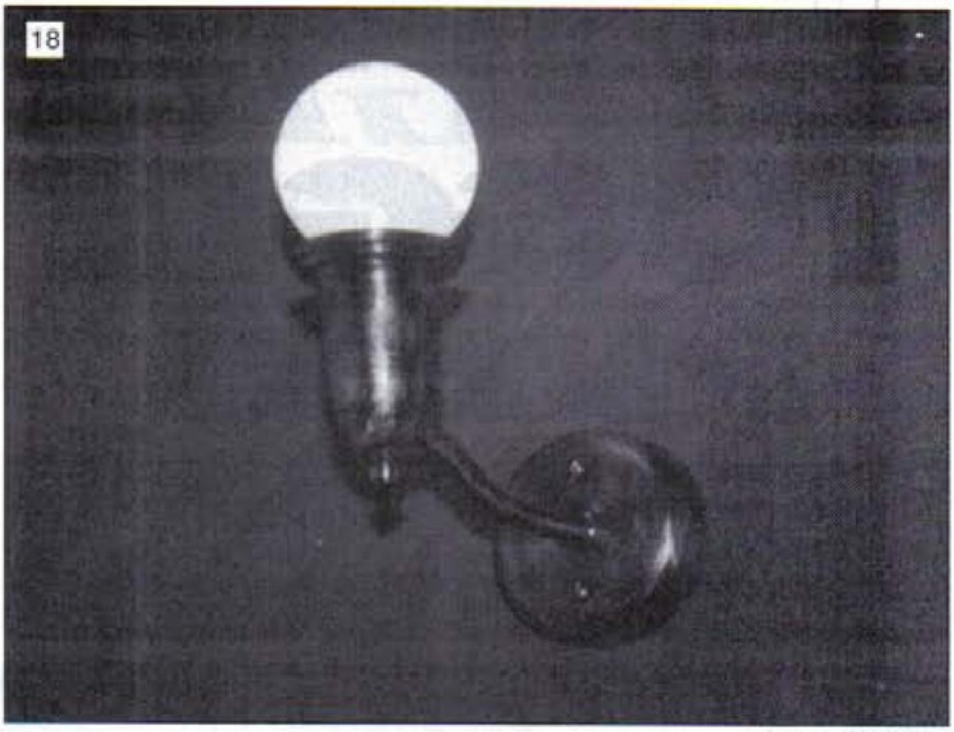
Cracks usually happen radially, at the outer edge of the blank when it is stretched too much without annealing often enough. Its incidence seems to be lessened by initially making the blank edge smooth, thus eliminating stress raisers. The only cures seem to be cutting off the offending zone of the blank, or repairing by silver-soldering or welding when the job is complete, and then dressing back to size. Cracks can also occur circumferentially when longitudinal pressure from the tool is applied too enthusiastically, especially if annealing not carried out at frequent intervals **(Drawing 17B)**. Besides thinning at point A when the material is soft, it can also crack there after it has work hardened **(Photo. 16)**.

Ripples occur when the spinning action does not sweep far enough out on the blank, or if the material further outboard has been worked before the inboard segment has been made to lie down on the former **(Drawing 17C)**. Ripples can sometimes be spun out, but otherwise hammering (7oz. hammer) with axially glancing blows against an anvil beak inside the job, or against the former, usually remove them. In either case, annealing is a prerequisite. Wrinkles occur when attempts are made to spin out wide ripples. The material is selectively forced down on to the former or stands proud **(Drawing 17D)**. The only remedy for this trouble seems to be the hammer and anvil technique. Again annealing is essential. If there is a mounting hole at the centre of the blank it will be found to increase in diameter as the work continues. If the job clatters about in the early stages, before it has been, at least, in part bedded down on the end of the former, it may also tear at this place. This enlargement is hard to prevent, and must be repaired at the completion of the job.

Conclusion

In due course, all the spun items were completed and silver-soldered or mechanically joined together to form one three branch centre light fitting and four single branch wall brackets **(Photos. 17 & 18)**. Quod erat faciendum (Which was to be done). They seem to satisfy the distaff side of the household.

The "have a go and you'll learn by experience" advice is certainly true, but the learning is probably faster if some actual detailed information is available, and if the operator is quite sure what is being attempted. Having fallen into most of the traps and pitfalls, I feel that the recounting of this saga may be helpful to others headed down the same track.



Wall bracket light

Appendix 1 The theoretical calculations

To get an idea of what is happening during the spinning process, consider an (over) simplified picture of the blank and former as shown in drawing 11(a) which is like a cantilever beam fixed at A.

From Ref. 14:

Deflection y of a cantilever beam loaded at its free end

$$y = PL^3/3EI \qquad \text{(i)}$$

where
P = load applied
L = length of beam
E = modulus of elasticity
I = moment of inertia of beam section
c = distance of extreme fibre from neutral axis

Bending moment M at support A -

$$M = PL \qquad \text{(ii)}$$

Stress S in beam at support A -

$$S = Mc/I = PLc/I \qquad \text{(iii)}$$

From which it is seen that the stress at the support is proportional to the length of the beam, but the deflection at the end of the beam is proportional to the cube of the length.

In the diagram, suppose that a load P1 applied at a distance L1 from the support is just sufficient to deflect the blank until it contacts the former (i.e. y1 becomes 0), and also suppose this is just sufficient to cause the stress S1 at the point of support A to exceed the material's elastic limit,

then $y_1 = P_1L_1^3/3EI$

$M_1 = P_1L_1$

and $S_1 = P_1L_1c/I$

Now contemplate instead, applying a load twice as far out along the beam. The load P_2 necessary to deflect the blank twice as far (y_2) will be

$$y_2 = P_2L_2^3/3EI$$

Rearranging terms we get

$3EI = P_1L_1^3/y_1$

and also $3EI = P_2L_2^3/y_2$

As $L_2 = 2L_1$ and $y_2 = 2y_1$

then $P_1L_1^3/y_1 = P_2(2L_1)^3/2y_1$

Therefore $P_2 = P_1/4$

Bending moment $M_2 = P_2L_2 = P_12L_1/4$

$= M_1/2$

which, by definition above, is only half that necessary to exceed the elastic limit for the material.

Let us now consider the use of the backstick to provide 'outboard' support of the blank in drawing 11(b). This is like a cantilever beam also supported at its free end.

Again, from Refs. 14 and 15:

For a load P in the centre of the beam, the bending moment M at the fixed end A

$$M = 3PL/16 \qquad \text{(iv)}$$

and deflection y at the centre -

$$y = 7PL^3/768EI \qquad \text{(v)}$$

so $y_1 = 7P_3(L_2)^3/768EI$

$= 7P_3L_1^3/96EI$

Rearranging terms -

$3EI = 7P_3L_1^3/32y_1 = P_1L_1^3/y_1$

therefore $P_3 = 32P_1/7$

and $M_3 = 3P_3L_2/16$

$= 3 \times 32P_12L_1/16 \times 7 = 12M_1/7$

This is nearly double the previous (unsupported) bending moment at A, so the deforming stress is easily attained.

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