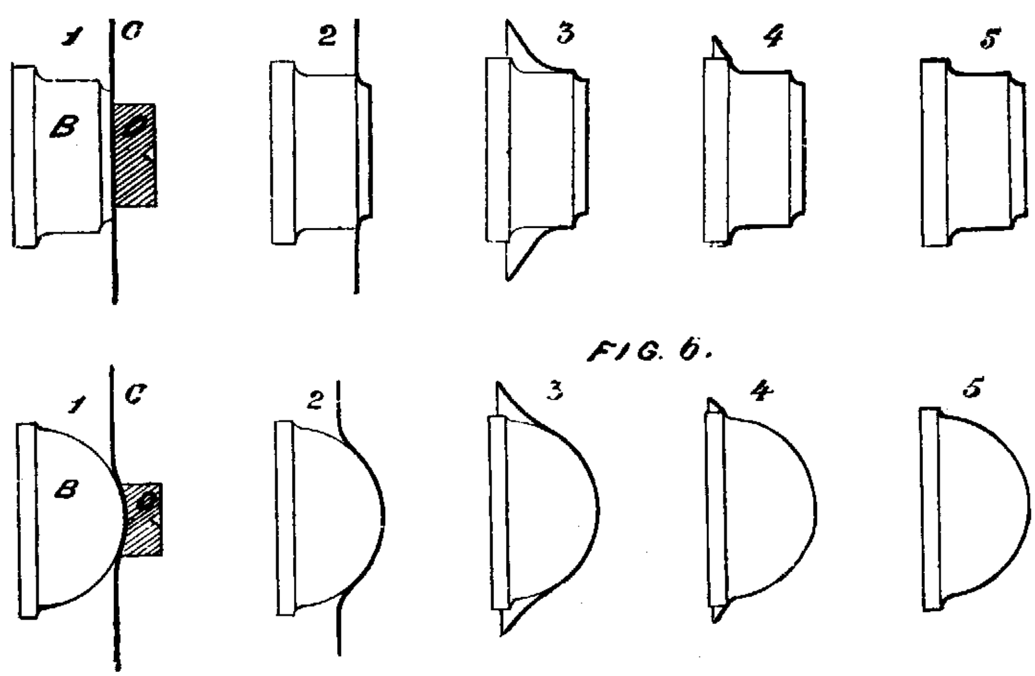
Metal Spinning Tutorial

PROCESS

Spinning sheet metal on the lathe is an excellent means for quickly prototyping round hollow metal forms (primarily the realm of expensive sheet metal stamping machinery). A levered force is applied uniformly to the sheet metal by rotating the metal and its intended form (mandrel) at very high rpms, thus the sheet metal is deformed evenly without any wrinkling or warble. The spinning process allows for the rapid production of multiple parts as well as quick reiteration since only the one tool (the mandrel) need be modified.

Depending on the complexity of the part being spun, spinning can be highly demanding physically. The more comfortable one gets with the process, and using one's muscles to just guide the tool and one's body to apply the force, the easier it gets (great for developing strong hands).

The final product should have a mirror sheen, or until one is more skilled with the finishing tool, small concentric annular grooves on the exterior surface. The interior surface (against the mandrel) should be as smooth as the surface of your mandrel. Metals harden as they are worked which sometimes necessitates annealing the piece partway through a spin, but often this isn't necessary and the metal hardens to a desirable stiffness as the part is spun.



APPLICATIONS

Spinning is a great means for manufacturing low cost rapid prototypes in metal, because it requires a minimum of time and money to produce parts. An average part can be spun in five to ten (5-10) minutes once one is familiar with the process.

Smooth parabolic curves (bell form) are ideal for spinning as the metal is comfortable deforming along a parabolic curve. The venturi form of velocity stacks for racing car carburetors is a common application of the spinning technology. A solid cylinder such as a Coca-cola can be spun, but a minimum of draft angle is required to pull the part back off the form (*see mandrel section for more*). Elliptical and off-center forms can be created, but they require great care and patience.

There is also the opportunity to create concentric strengthening ribs which add dramatically to the stiffness and strength of the part. These can be formed directly (over the mandrel) or spun in the air (tricky) as the part is closed down onto the mandrel. An edge may also be folded over itself or with wire inside to create a finished, smooth edge to the part.

METALS

Almost every metal that is available in sheet form may be spun (tubing can be pinched or swaged but is usually made from harder alloys). However, a few metals are ideally suited to the art of spinning. Aluminum is fantastically elastic and easy to form so long as it has been annealed. The softer (i.e. purer, non-alloyed) the aluminum the better. Hence, 3003 is better than 5052 , and 1100-0 is the best to use especially since 3003 doesn't anodize very well. However, 5052 is the strongest work hardening aluminum, but harder to form. Try to buy the aluminum sheet annealed (1100-**0,** 3003-**0,** etc.; **not** 1100-H**32**, 6061-T**6**, etc.). **H** denotes strain hardenable aluminums and **T** denotes thermally treated aluminums. Sheet metal can be spun in thicknesses of 0.040" to 0.100" with hand tools.

Stainless steel is even more elastic (stretching before tearing) than aluminum (50%-68% elongation!) but requires <u>significantly</u> more force to form. The *Austenitic* range (200-300 series) of stainless steels form best, 201 and 301 having the greatest elongation. Similarly, the lower the Carbon content in mild steel the easier it is to form. Copper has excellent elongation (very formable) and doubles its tensile strength when work hardened, but if it hardens before the part is finished then the part must be annealed to prevent shearing and cracking. Brass is a copper-zinc alloy and has similar properties to copper in its formability but brass work hardens less and requires more force. Other exotic metals may be spun: titanium, magnesium (@ 600°F), silver, gold, etc., but they require extra care and consideration.

CHART OF ALLOY COMPOSITION AND RELATIVE ELONGATION:

Generally, the greater the % elongation is the more formable the material.

Note: Recommended materials in **bold** face type.

Material	Alloy composition	% elongation for 2"
•Aluminum 1100-0	**99%Al**	**60% elongation**
•Aluminum 2014-T6	90%Al - 4.4%Cu - 1%Mg, Mn, Si	13% elongation
•Aluminum 3003-0	98%Al - 0.12%Cu - 1.2%Mn	30% elongation
•Aluminum 5052-0	97%Al - 2.5%Mg - 0.25%Cr	25% elongation
•Aluminum 6061-T6	1%Mg - 0.6%Si - 0.28%Cu, Cr	17% elongation
•Aluminum 7075-T6	90%Al - 1.6%Cu - 2.5%Mg	11% elongation
•Commercial Brass	90%Cu - 10%Zn	45% elongation
•Red Brass	80%Cu - 20%Zn	50% elongation
•Yellow Brass	**65%Cu - 35%Zn**	**64% elongation**
•Free Cutting Brass	61%Cu - 35%Zn - 3%Pb	60% elongation
•Phosphor Bronze	91%Cu - 8%Sn	65% elongation
•Manganese Bronze	89%Cu - 11%Mn	40% elongation
•Copper	**99%Cu**	**60% elongation**
•Nickel Silver (coins)	70%Cu - 5%Zn - 25%Ni	45% elongation
•Steel (low carbon)	98%Fe - 0.3%C - 1%Mn, Si, Cu	20% elongation
•Stainless Steel		
Martensitic: 400 - 500	92%Fe - 1%C - 10%Cr	10% elongation
Ferritic: 405,430,446	20%Cr - 0.2%C - 1.5%Mn	20% elongation
Austenitic: 201,301	**18%Cr - 0.1%C - 8%Ni**	**68% elongation**
302,304,310,321	26%Cr - 0.03%C - 22%Ni	50% elongation
•Titanium	99%Ti	25% elongation

Al=aluminum, C=carbon, Cr=chromium,Cu=copper, Fe=Iron, Mn=manganese, Mg=magnesium, Ni=nickel, Pb=lead, Si=silicon, Sn=tin, Ti=titanium, Zn=zinc

TOOLS

There are an infinite variety of tool profiles that can be forged in mild steel for spinning the material into different shapes. A long handle provides ample leverage to work the material down the mandrel in smooth efficient strokes. The wooden butt of the tool is placed in one's armpit such that one's body weight provides the force and one's arms are free to guide the tool in a smooth and precise manner. The tool is usually about three (3) feet long with a one (1) inch diameter steel rod forged into the preferred tool point.

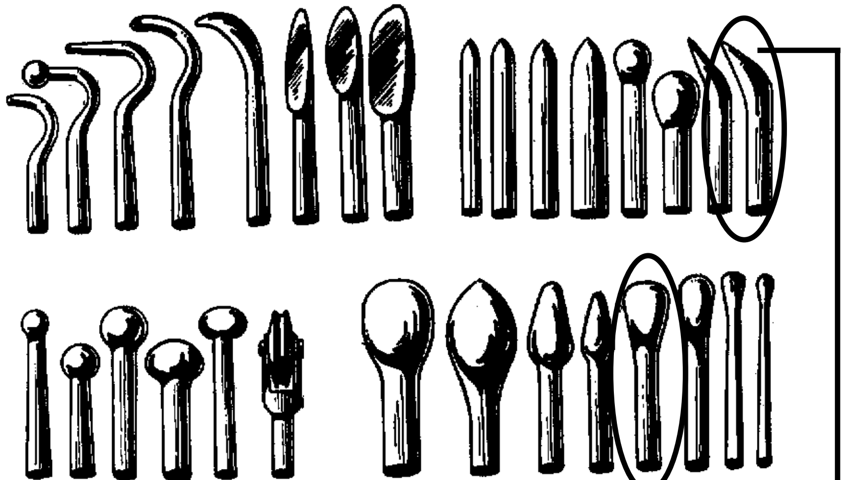


FIG. 147.—Types of spinning tools

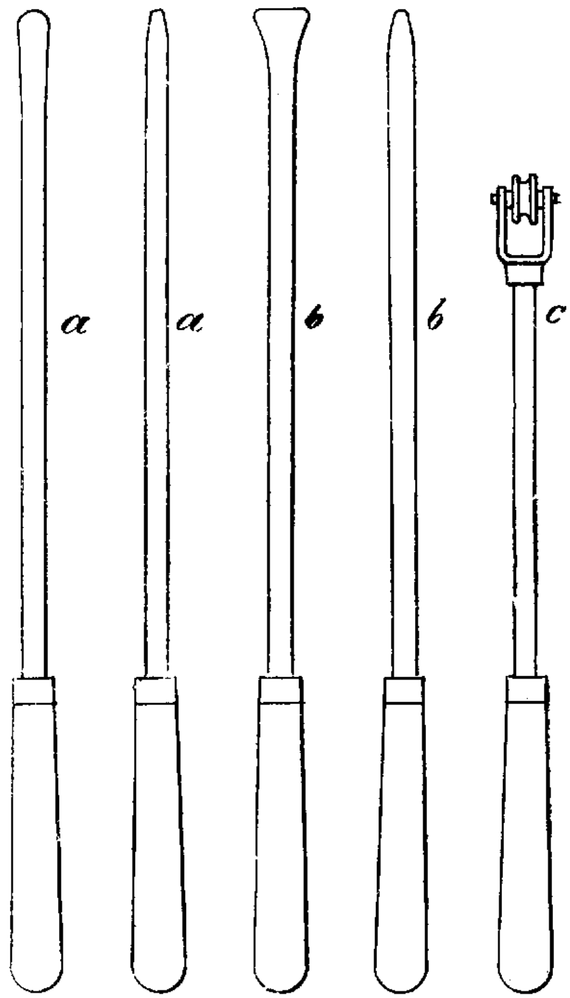
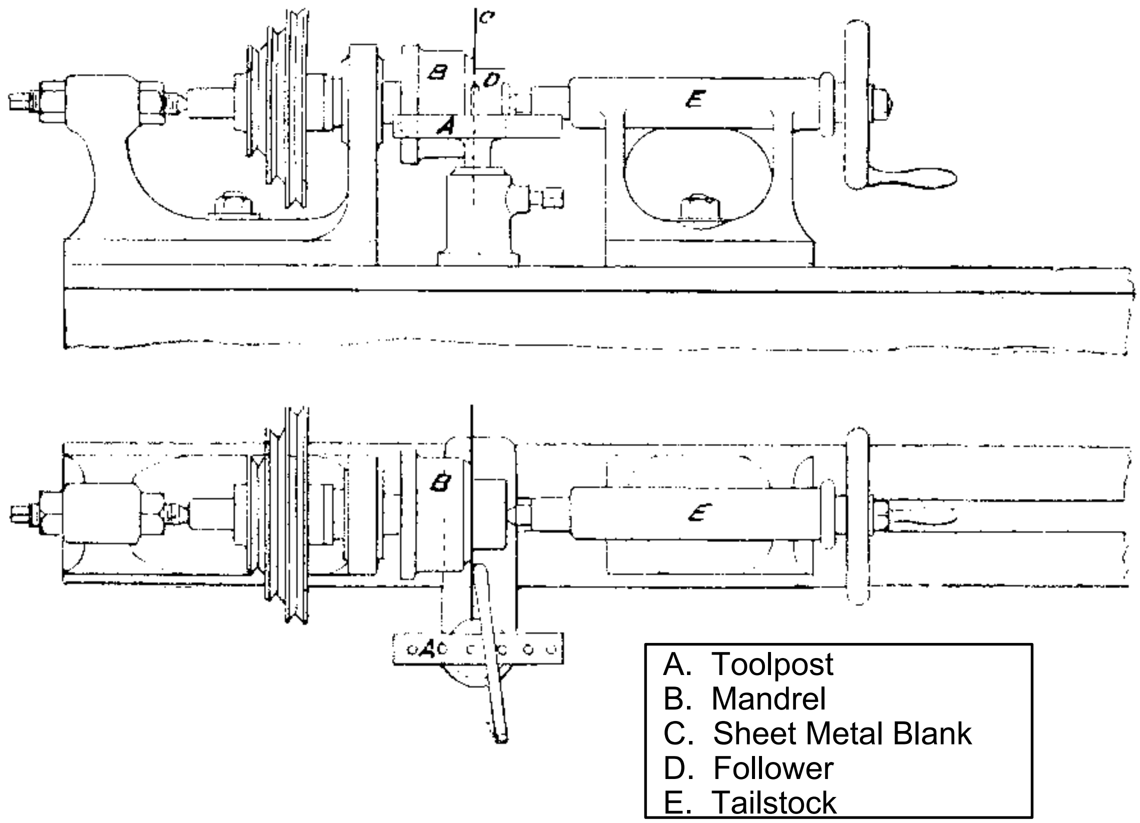


PLATE XIV.—TOOLS FOR METAL-SPINNING.

The primary tools are the *Sheep's nose* used for most of the forming, and the *Duck's bill* used for finishing (see *a & b* above) the fully formed piece. The hooked nose of the *Sheep's nose* is ideal for forming tight radii as well as having a decreasing radius that makes it easy to form the metal over a variety of curves. The *Duck's bill* has a flat side for finishing straight surfaces and a rounded side to finish curved surfaces. The tool post is essentially a rounded pin protruding from a boring bar mounted on the crossfeed such that the pin acts as a fulcrum around which the hand tool can be leveraged. The tool post is moved as the part forms down the mandrel so that a consistent lever arm is maintained.



Custom grooving or forming tools can be easily fabricated and even mounted directly to the crossfeed if it is a simple form. Spinning with the tool attached to the crossfeed limits one's ability to feel the material and form it smoothly. A compromise, for example, is swaging where a rolling tool forms the metal without a buildup of friction (i.e. bad surface finish).

Professional spinning shops typically use tools with rollers mounted on a five (5) foot long steel tube handle for forming everything (from lamp shades to pots) and a peg board mounted on the cross feed so that they can form the parts as quickly and efficiently as possible. There are also a few manufacturers that have CNC spinning lathes, but it is generally a lost art in the age of metal stamping.

Lubricant

A lubricating wax or grease is essential to a quality finish and just being able to remove your part from the mandrel. Stick wax works great although it gets lumpy sometimes. Grease doesn't lubricate as long and tends to spray all over the place. There are some special brown spinning waxes that last longer than the others, but it is messier than the grease. Therefore, stick wax (available at ShopTools or Danmar) is a great general-purpose lubricant. However, another lubricant might be better for use under the part on the mandrel to facilitate the removal of the part from the mandrel.

Gloves are an important safety and performance-enhancing tool. A leather welding glove worn on the left or clamping hand alleviates pressure and vibration causing fatigue and numbness. It also protects the hand from the spinning part. Cotton (not nylon) gloves can be worn for comfort as well, but the leather is, obviously, preferable.

Files and sandpaper can be used for final finishing, but as one gets more proficient at spinning sanding shouldn't be necessary.

Another necessity is a grungy workshirt as any lubricant will spray one's attire with a nice Dalmatian pattern.

SAFETY

Since one is spinning at very high speeds and applying a large amount of force by hand, safety awareness is **essential**. Directly mounting the mandrel to a headstock plate (there are a couple on the lathe bench) is preferable as there are no protruding jaws to run into with the tool or one's hand. This has the added benefit of automatically centering your tool every time you mount it on the lathe (**highly recommended**). The 3-Jaw chuck is the biggest danger one will confront when spinning. If the mandrel is chucked up in the 3-Jaw then one should leave plenty of room between the 3-jaw and the finished part and exercise extreme caution when the tool is anywhere close to the 3-Jaw. The use of the 3-Jaw also prohibits turning the lathe at high rpm's for finishing (max. 1000rpm with 3-Jaw).

It is important to be aware of what state the material being spun is in, i.e. is there localized hardening, are there thin spots, likely shearing or wrinkling, etc.? Make sure the tailstock is clamped tightly as well as all the headstock bolts and tool post. Always move the tool post away from the part when sanding or filing so that it doesn't catch on anything. If the part fails (shear or extreme warpage), brake the lathe fully and stop the part with a tool before it sands a groove into the mandrel.

Wearing a glove on the left clamping hand will protect one from the sharp edge of the spinning part and absorb vibrations that cause numbness. Use one's body weight to apply the force to the part so that the arms are free to guide the tool, otherwise one will fatigue very quickly and not be as smooth and precise (see forming section). Curl one's fingers over the tool post and away from the part. File sharp edges off of part to eliminate burr cuts, but be sure to clean all chips and debris off the mandrel or it will scratch the mandrel and damage the part.

MANDREL

The mandrel or buck is the form over which the sheet metal blank is formed. There are limits to the shapes one can spin, but, generally, the more complicated the form the greater the need for care in machining the mandrel. As mentioned in the Safety section, it is highly recommended to mount your mandrel directly to a headstock plate with at least three (3) 3/8"-16 bolts. Once bolted and centered on the lathe all subsequent machining will create a perfectly centered mandrel (every time you remount, too). If the 3-Jaw must be used with the mandrel then a centering hole in the end of the mandrel is imperative for re-centering.

The mandrel can be machined from a variety of materials, each of which has its own cost and strength attributes. Renshape and wood are the cheapest buck-making materials, with Renshape less likely to hold an edge without cracking where wood will deform after repeated spinning efforts. Wood mandrels are excellent for simple bowl and bell forms (no hard corners). Aluminum mandrels are fairly sturdy but tend to gall, especially if spinning aluminum over them; not recommended unless spinning copper or other soft metals.

Steel Mandrel

A mild steel mandrel requires extra up front machining (a carbide tool works wonders), but it yields a superior finish surprisingly easily (a file, then 120-600 sanding), holds sharp corners and subtle radii through multiple parts (up to the 100's), and stays centered. A smooth finish is essential to removing the part without damaging it. When finishing the face of the mandrel extra care should be exerted with steel so that the mandrel isn't knocked off center necessitating shimming and retorquing (been there). A half center is a useful tool for finishing the face with the alignment help of the tailstock.

Therefore, if one is spinning a simple form and only needs a few parts, a wood or Renshape mandrel can be used. If one is attempting to spin a more difficult form and needs a greater number of parts and/or attempts, then steel is highly recommended (besides it's satisfying to machine).

It is important to design the mandrel with at least a 1° draft angle so that the part can be removed from the mandrel. Smooth curves are the most forgiving forms for spinning, but sharp corners can be accomplished as long as the material isn't stretched to quickly. The general rule for the overall proportions is for the mandrel to be shorter than it is wide, but as one gets more skilled at spinning these rules can be pushed.

Undercuts

The part can't be removed from the mandrel if there are undercuts, but if necessary parts can be spun with undercuts if the mandrel is divided into pieces that can be notched and bolted together, and most importantly unbolted without damaging the finished part.

It is advisable to leave at least 2-4" of mandrel beyond the desired finished part length (toward the headstock) so that the part can be finished cleanly and without the danger of back extrusion (the part will literally extrude toward the tail stock if it has nowhere to go forward). It is preferable to have a small dimple or otherwise non-flat face on the mandrel so that the sheet metal blank will stay centered during the spinning process when sandwiched between the mandrel and a follower in the tailstock (see lathe section).

It is possible to spin an elliptical or asymmetrical form, but it requires extreme skill and moral turpitude.

LATHE

The headstock is the driving face of the lathe and is the side to which the mandrel is mounted, preferably on a headstock mounting plate rather than a 3-Jaw chuck as emphasized in the Safety section.

The tailstock is clamped down securely with a live center pressing against a follower (usually aluminum or steel) made to reflect the shape of the mandrel face such that the sheet metal blank is sandwiched tightly against the mandrel and can't slide out.

Spinning should be accomplished at 900-1200rpm for forming, and 1800rpm for finishing (but max. 1000rpm if using 3-Jaw chuck). The tool post should be moved to follow the form every 2-3 inches.

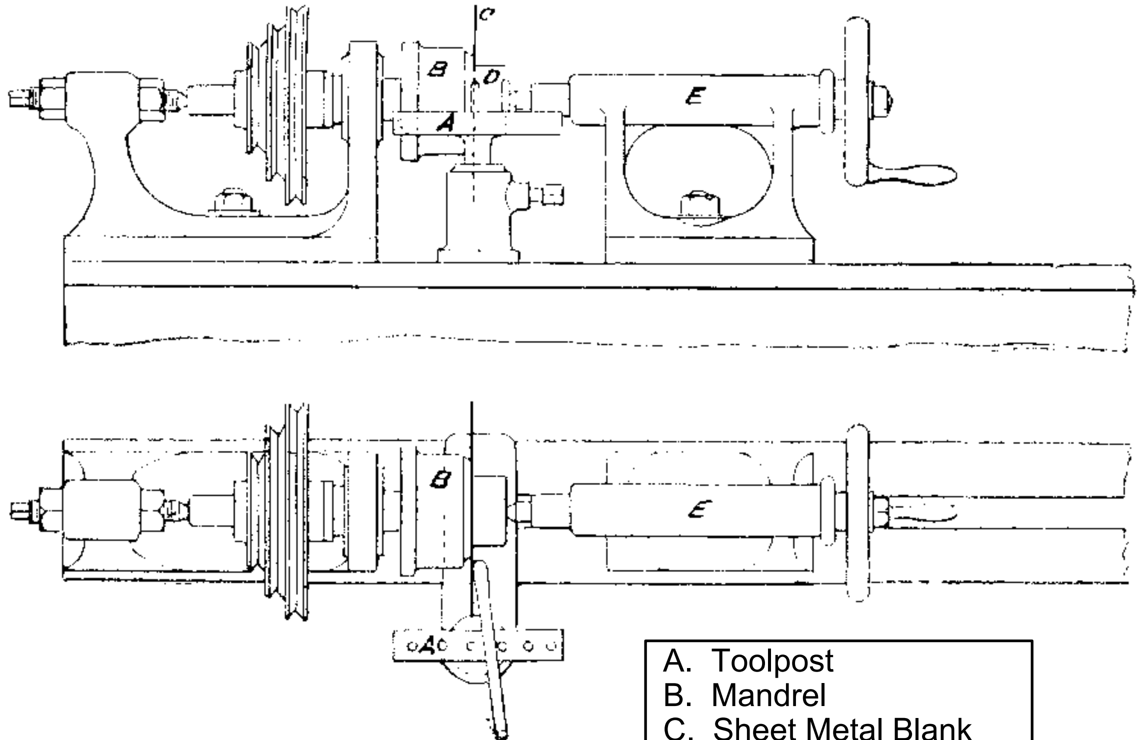
Precision centering of the mandrel is critical to final finish and the overall ease of spinning (very sore armpits from eccentric chatter).

FORMING

Forming is accomplished by working with the material, feeling its structure, its grain, its hardness, its willingness to move in the directions that you want it to. It is critical that one be sensitive to the material's willingness to move so that you can force the material down the mandrel smoothly, quickly, and most importantly, evenly. Smooth, even rowing strokes are the key to spinning good parts.

One should spin it thin and smooth, like throwing a thin wall clay pot; in fact, the process of spinning sheet metal is remarkably similar. One must push enough material down onto the mandrel without stretching or warping the remaining material so that a smooth, steady draw of the material over the mandrel is accomplished.

The sheet metal blank should be a disc approximately equal in radius to the desired part's length plus radius times 80%[$D = .8(l+r)$].



A. Toolpost
B. Mandrel
C. Sheet Metal Blank
D. Follower
E. Tailstock

One's body weight and the fulcrum of the tool post are used to create a powerful lever arm that almost effortlessly moves the material down the mandrel. The effort comes in trying to direct and smooth the material. So, it is important to save one's arm and hand energy for guiding the tool and not for applying force to the part. As mentioned in the Tools section, the wooden butt of the 3-foot long spinning tool is placed in the armpit and held in place with the right hand near the middle and the left hand curled around the tool post securing the tool to the pivot or fulcrum. Once the lathe is turning, one holds the tool as described and leans slowly down and to the right while sweeping the tool smoothly across the part from inside to outside (right to left).

The hooked tip of the *Sheep's nose* tool should be placed below the follower (at 6 O'clock) for maximum force with the least amount of chatter. Initially, small orbital strokes near the center of the part (or as near to center as the follower allows) should slowly push the sheet metal blank into a flared bell shape, again moving inside to outside. Exert care because the part is not yet seated and could easily be knocked off-center.

Seating the Part

Once the blank has been flared about 1" then the part should be persuasively pushed against the mandrel so that at least the top 1/2" of the part is seated securely on the mandrel. A solid drone is discernible when there is no gap between the part and the mandrel. If seating on a mandrel with a sharp edge extra care should be taken not to overwork the edge (cracking) while still assuring a secure seating of the part.

Once the part has been seated then it is merely a matter of patience as the rest of the forming follows quite predictably. The bell curve or hyperbolic flare is the shape the material wants to take, so one allows it to go where it wants so long as there is a valley to push down onto the mandrel and a hill or bump to keep the outer edge from warping or mis-aligning when the blank is stretched down onto the mandrel. For simple bowl and bell shapes a bump isn't necessary, but for more complicated (especially more cylindrical) forms maintaining a bubble near the outer circumference of the blank is critical to prevent warping and warbling.

Forming Motion

The laying down of the material onto the mandrel is accomplished with short inside to outside moves, but the bump is smoothed from the outside back in such that the top of the bump is smoothed to the inside with several gentle strokes, then when the material (the valley) is laid down onto the mandrel the bump will flare out again.

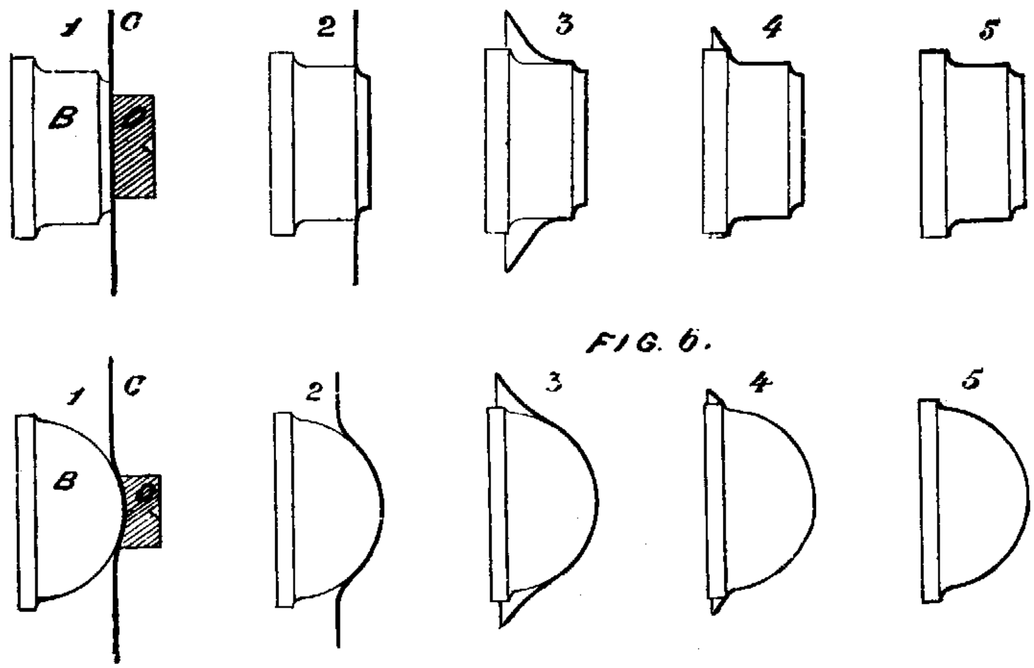


FIG. 6.

The material will get easier to move as the part is closer to completion (unless it has work hardened too much in which case it should be annealed), but patience must be exercised so that the fully formed part requires a minimum of finishing. Just keep repeating the same smooth fluid strokes from inside to outside until the part is seated and then start to move the material from the outside in, but always try to leave a bump or rib to protect against warping and over-stretching.

Flaring

Sometimes, the part will flare too much toward the tailstock when laying the part down too hard (maintaining a rib prevents this). Several cleaning swipes from inside to outside with extra force applied at the end of the stroke should form the part back to a subtle flare. Alternately, the part will sometimes fold toward the headstock in which case strong cleaning swipes from inside to outside with extra force applied in the middle should pop the part back toward the tailstock. If not then the part may be worked from the backside, but this is not very clean.

If warbling occurs try to wipe it out with smooth **hard** strokes, but if the warbles are along the edge then a wood stick (with the spinning tools) with a slot in it can be forced over the edge of the part and twisted while steadying on the tool rest which should smooth the warbles. **Important**: keep the mandrel and part clean of any chips or debris to prevent scratching of the mandrel and damage to the part; and clean the part and **re-lubricate** when there are any signs of material build-up, especially with gall-happy aluminum.

Trimming

Remember to plan for trimming part at end; cutting tool can be mounted on tool rest, but may leave a groove in mandrel (prohibiting finishing past that point on future parts); so bandsaw and belt sander are a safe trimming option, especially if unsure of desired final length.

FINISHING

Finishing is accomplished with smooth right to left sweeps with the *Duckbill* spinning tool using the flat side for straight surfaces, and rounded side for curves and radii. The *Sheep's Nose* tool can be used for tight corners, but the duckbill is favored for most finishing. Finishing should be done at very high rpm's (1200+rpm) so that a minimum of force need be applied and very smooth fluid strokes can be used.

It is important to feel the material on a more subtle level when finishing, the hills and valleys felt during forming are now very minute and require extra sensitivity to smooth the hills into the valleys. A push and release rhythm of hills into valleys literally moves a few thousandths of material down the part so that an even, smooth finish with fine annular grooving is achieved. **Careful** of working one area too thin or overheating, which causes stress fractures.

CRAFT

Spinning is truly a lost art form in the age of deep draw metal stamping, but it is much more economical (for runs under 100,000) and yields a more perfectly finished final part (no stretch marks). It is a fantastic process to establish an intuitive sense of materials and how can best take advantage of a material's intrinsic properties. There is a sense of quality inherent to the process of metal spinning that makes it a true craft. Developing a feel for the material with all of one's senses allows one to push the material and the spinning process to yield a perfect part effortlessly. Listening to the tool on the part; feeling the resistance of the material; learning the rhythms of spin forming; interacting with the structural transformations that are occurring as the part is formed down the mandrel are key to the art of spinning.