FORMING

SPINNING AND FLOWTURNING STEEL SHEET AND STRIP

TECHNICAL BULLETIN TB-F8

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1 SPINNING AND FLOW TURNING PROCESS

The art of spinning metal dates back to the days when the principle was applied to the making of armour.

Today, while by no means as popular as pressing and drawing, spinning provides a cost effective means of forming lower volume and prototype items in cases where the cost of dies and setting up would be prohibitive for small production runs. In some cases, spinning has advantages over pressing with smoother inside surfaces and ability to easily add rolled edged or other features.

In the case of spinning, the required skills are born of practice and troubleshooting should recognise this fact before becoming too involved with material quality.

Spinning and flow turning processes are sometimes wrongly grouped under the general heading of spinning because of outward appearances of similarity, but in effect, the physics of each process are different.

Spinning and flow turning are both versatile forming processes used for production of hollow components with circular cross-sections such as cones, cylinders and hemispheres. Parts deviating from this symmetry such as ovals, ellipses, circular designs in flat surfaces and occasionally simple non-circular shapes, such as rectangles can be spun using special equipment.

A flat steel blank (*disc*) or preformed workpiece is clamped in a rigidly constructed lathe between a spinning chuck (*mandrel, former or form-block*) attached to the headstock and a pressure plate (*friction block, follow block or follower*) attached to the rotating tailstock, (*Figure 1*). A power or hand-operated tool, steadied in position by an adjustable support which allows it to be moved along the surface of the component, is used to apply pressure to the revolving blank so as to deflect the unsupported portion, usually onto the chuck. The material is moved by a series of stroking actions commencing as near as necessary to its centre and gradually moving the tool out to the periphery as the desired shape is achieved.

Simple shapes can be spun on air, that is, without a suitably shaped chuck, but as this requires great skill, a chuck profile is usually used. For small production runs craftwood chucks are used but for longer productions, the chucks are made from steel.

A hollow chuck is used to hold preformed workpieces requiring further forming by spinning; for example, a deep drawn component to be necked down to a smaller diameter at the open end, or workpieces to be expanded or stretched. Sectional chucks are made up of segments which can be dismantled to allow easier removal from necked workpieces.

Workpieces are usually spun without heating but to increase ductility or reduce the strength, the blank may be preheated. The practical maximum thickness of low carbon steel that can be spun without mechanical assistance is 3 mm, which can be formed with diameters up to 1800 mm, or greater with a thinner blank. The upper thickness limit increases as the ductility increases and the strength decreases. Shallow components are commonly made from thinner materials but the use of blanks under 0.5 mm is generally too difficult for the operator for deeper components.

Spinning provides an efficient and economical alternative to some of the more common forming processes and for low volume production of items such as domestic hollow-ware, industrial light fittings, trays, concrete mixers, tank ends and shields. It is also used for production of components subject to frequent design changes or components so large that other fabrication methods would be prohibitively expensive. There is no waste of material from machining or formation of chips. The only loss results from trimming off the rim to make the workpiece the exact size.

Spinning can be combined advantageously with other forming operations such as deep drawing, bulging, beading and flanging, and is a valuable finishing operation for trimming, ironing and rolling of circular drawn parts.

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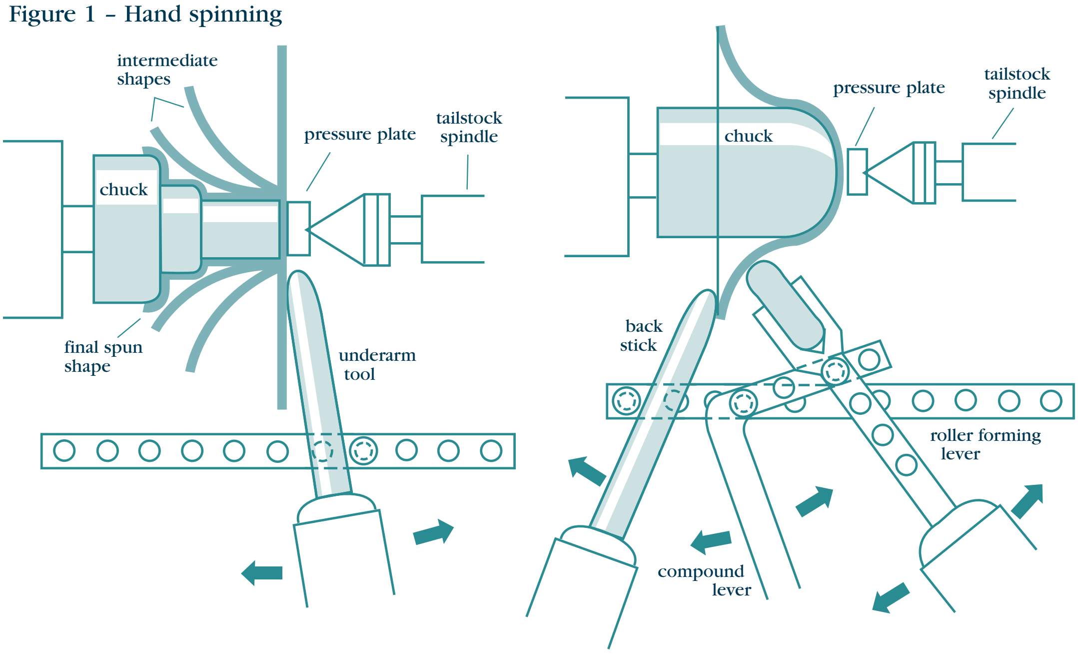
Figure 1 – Hand spinning



(a) Underarm tool method

(b) Lever or scissor tool method

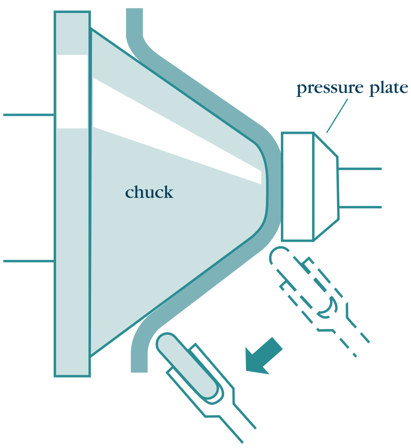
2 SPINNING AND FLOW TURNING TECHNIQUES

The two basic processes are manual spinning and flow turning.

Manual Spinning can be hand done, mechanical, power assisted or automated. There is little variation in the wall thickness of the finished component so both the final thickness and final surface area remain virtually that of the blank. For very deep components, some reduction of metal thickness does occur.

Flow turning covers two processes - shear forming and flow forming. Shear forming is used for the production of hollow conical components from a circular flat blank but is different to spinning in that material flow results from the application of shear forces. These forces give a reduction in thickness of the blank or preform used as illustrated in Figure 2.

Figure 2 – Shear forming



Flow forming is an elongation process for reducing the wall thickness of a thick-walled cylindrical preform to produce a cylindrically shaped final product.

Flow turning is characterised by a constant diameter from the blank to the finished component. In some countries flow turning is known by various other names such as shear spinning, compression spinning, power spinning or tube spinning.

2.1 Manual Spinning

2.1.1 HAND SPINNING

The two basic hand spinning methods are the:

- Underarm tool method where the operator uses his own muscle power to apply the tool pressure as he forces the blunt-nosed tool-steel bar back and forth across the rotating blank (*Figure 1a*).
- Lever or scissor tool method where a combination of a long roller-forming lever and a compound lever allow high forces to be manually applied and thus larger or thicker workpieces to be formed (*Figure 1b*). The acceptance of this method has been largely restricted by the additional benefits to be gained from mechanical slides (*refer to Mechanical Spinning*) to control the forming tool.

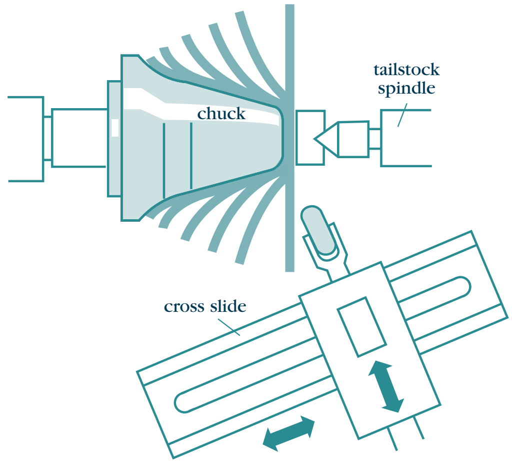
In both cases the forming force is generally applied mainly in the direction tangential to the surface, causing the metal to flow in shear without thinning. Both processes are restricted to thin sheet by the physical strength of the operator. They are slow and labour intensive and require considerable skill.

2.1.2 MECHANICAL SPINNING

For workpieces too large or too thick to hand spin, mechanical assistance can be provided by a lathe with transverse and cross slides (*Figure 3*). Turning hand wheels on the slides causes the tool to traverse the workpiece as required.

Slides can be used in conjunction with a spring-loaded roller tool to spin parts which deviate only slightly from circular. Oval workpieces are also spun using slides but in this case the lathe has special headstock and tailstock equipment and the blank is oval to begin with.

Figure 3 – Mechanical spinning using cross slide



2.1.3 POWER ASSISTED SPINNING

When spinning thin material a screw-driven tailstock provides the necessary clamping force, but for thicker or high strength steel much higher pressures are required and a hydraulically operated spinning lathe is used. Both the tailstock cylinder operating the tailstock shaft and the two feed systems of the compound rest which carries the tools are hydraulically power assisted.

The physical strength required of the operator is no longer essential in power assisted spinning but the quality and accuracy of the final component still depend directly on his skill and concentration. This degree of dependence can be reduced by automatic spinning (*refer to Section 2.1.4*) but many trade spinners prefer hydraulic spinning machines because of their versatility and low resetting time for small batch production. The chuck and possibly the spinning roller are all that need changing to reset the machine.

2.1.4 AUTOMATIC SPINNING

The high production advantage of alternative forming processes over spinning is eliminated by automatic spinning which achieves high quality workpieces with economical high volume production. Automatic spinning is either template or numerically controlled.

2.1.4.1 Template Control

A stylus controls the hydraulically operated roller by following the template contour which determines the component shape. The production sequence is programmed by a swivel template or a stack of templates which allows different sizes, shapes and materials to be accommodated. However, this system has the disadvantage of up to three to four hours resetting time.

2.1.4.2 Computerised Numerical Control

The tool path is electronically controlled thereby eliminating templates, reducing programming and resetting times and making feed speed programmable and infinitely variable. Computerised numerical control results in a very high degree of surface finish and produces a wider range of workpiece shapes using blanks up to 1200 mm in diameter.

The operator can control two to three automatic spinning machines concurrently because all that he is required to do is remove the completed workpiece and insert another blank. In addition to performing general spinning operations, automatic machines may also incorporate auxiliary equipment for operations such as beading, trimming or forming of circular seams between the base and the sides of cylindrical or conical containers, such as washing machine and spin drier drums.

They are also commonly used for necking in such products as kettles, teapots or motor cycle exhaust systems.

3 FLOW TURNING

3.1 Shear Forming

Shear forming is a flow turning process by which rotationally symmetric conical, convex or concave components are formed to extremely close tolerances. It is frequently used in conjunction with other forming processes such as manual spinning or deep drawing to produce a wider or more complex range of components, including conical light fixtures, air diffusers and deflectors.

In shear forming as in manual spinning, a flat blank or preform is clamped against the chuck by the action of the tailstock, and rotated. But in this case a specially shaped shear forming roller proceeds under high pressure parallel with the revolving blank forcing it onto the chuck (*Figure 2*). The roller maintains a preset gap through which the metal is extruded to produce the required thickness.

From start to finish, the unformed section of the blank remains at right angles to the axis of rotation, keeping the diameter constant. The surface area increases, but since no metal is removed the material volume remains constant.

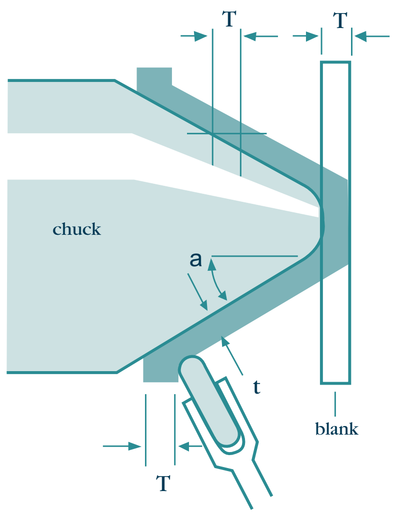
The components formed can have straight or curved walls the thickness of which depends on the angle a between the wall and the axis of rotation (*Figure 4*), and is related as follows:

Final wall thickness = Blank thickness x sin a

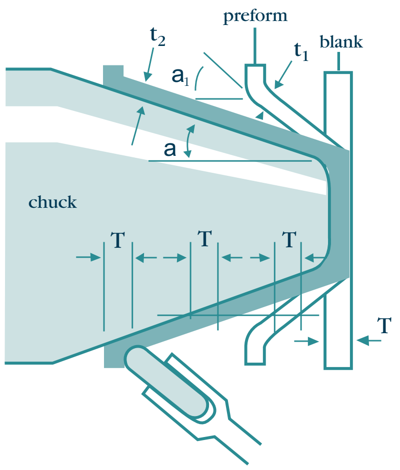
When a preform of thickness t_1 and an angle a_1 (*Figure 4b*) is to be used, the final thickness t_2 is found from the formula:

$$t_2 = t_1 \frac{\sin a}{\sin a_1}$$

Figure 4 – Relationship between initial and final wall thickness in shear forming from (a) a blank and (b) a preform.



(a) blank



(b) preform

When a is outside the range of 13 to 80° the feasibility of shear forming should be seriously considered. Below 12° thinning and metal working are excessive, beyond 80° the blank becomes unstable.

Higher forces are required in shear forming than in manual spinning because in addition to reshaping the blank it also reduces the metal thickness. Forces are applied only at the point of contact between the roller and the workpiece (*Figure 2*), so the rest of the material is not stressed.

The higher force involved also necessitates more rigid machines than does manual spinning. The roller is controlled by regulating the roller in-feed cylinder pressure or by a hydraulically operated copying device and template system. The use of the latter system compensates for variations that might occur in material batches.

There is considerable work hardening in shear forming due to the high degree of deformation occurring, so thinner walls than would normally be possible in other processes can be produced with material savings. Many of the steps required in alternative operations are eliminated in shear forming which is generally completed in one roller pass. The machine is then quickly and easily reset and needs only semi-skilled operators.

4 FORMING VARIABLES

4.1 Lubrication

Lubrication is needed for all room temperature spinning operations to reduce the friction between the tool and the workpiece and thereby improve surface finish. One of the principle requirements of the lubricant is that it adheres to or wets the rotating blank.

Soluble oils and waxes are suitable lubricants for manual spinning but bar soap (*yellow naphtha soap*) with or without a light coating of grease is commonly applied.

In flow turning the lubricant must also act as a coolant to remove the heat generated by the metal deformation. A colloidal suspension of zinc/lithium soap or molybdenum disulphide paste mixed with water is generally used.

4.2 Speed

In manual spinning the optimum surface speed is determined by operator feel and is dependent on the properties and thickness of the steel. A lineal surface speed for manual spinning of mild sheet steel of 800-900 m/min is normal.

Flow turning speeds are 300-600 m/min irrespective of the metal properties, workpiece shape or reduction in thickness in each pass.

4.3 Points of Technique

To ensure minimum scrap loss the edge of the blank should be free of burrs or nicks which can initiate cracks. Any welds should be dressed off flush with the surface to prevent local thinning.

Spinning time can be reduced and centering simplified by blanking and pressing a recess of size equal to the base of the spun part in a single operation.

To prevent excessive thinning when forming sharp outside corners the metal can be loosely spun over the radius then compressed back snugly onto the chuck. Re-entrant corners can be formed by spinning the metal across the corner then stretching it into the corner using well rounded tools to avoid cutting the metal.

During spinning, high stresses build up in the unsupported metal away from the chuck and tend to produce wrinkles. In blanks of large diameters a back stick which presses against the reverse side of the blank can be used to prevent wrinkles (*Figure 1b*) or else to move them out to the rim where they can be trimmed off. If the metal is stretched too much, causing unwanted thinning, a pass from rim to centre will thicken up the wall again. Wrinkling can be minimised by using multiple passes, each pass slightly overlapping the previous one and the last part of each pass is spun on air.

5 SELECTION OF PRODUCT FOR SPINNING

Since these spinning operations do not develop tensile stresses in the part wall as does the drawing process (*where the drawing force acts through the walls to shape the blank*) metals of low ductility can frequently be spun to quite complex shapes.

Thus the higher strength characteristics of these reduced ductility products can possibly be used for shells requiring greater strength and dent resistance than attained from the more ductile products typically used.

Problems can arise when spinning ZINCALUME® G300 zinc/aluminium alloy coated steel and ZINCFORM® G300 steel because of a heavy microflute pattern in the base steel of the blank. These products are flattened during processing by tension levelling which produces a pattern of alternate transverse bands of worked and unworked areas in the steel base. During prolonged storage the worked areas age harden and this change can allow the unworked areas or bands between the microflutes, to stretch during the spinning operation in preference to the now age hardened and hence less ductile, bands of microflutes. This inability to adequately distribute strain can cause splitting of the part. Thus for some spun shapes it may be necessary to use feed which has a very light microfluting pattern or has not been stored for long periods.

If ZINCALUME® zinc/aluminium alloy coated steel is spun, it is likely that the resin coating will be removed on the tool side. Pick up of resin onto the tool might also occur. Should this be an issue, the use of GALVALUME® zinc/aluminium alloy coated steel (non-resin coated), is recommended.

6 ADVANTAGES OF SPINNING AND FLOW TURNING

Many hollow cylindrical components can be produced by spinning or flow turning or a combination of both. Spinning or flow turning are suitable when the part:

a) has rotational symmetry
b) has undercut (*necked or convex*) areas or large depth, and
c) is only required in small batches.

Spinning and flow turning are slower more labour intensive operations requiring higher skilled operators than press forming, but have lower tooling costs and investment in capital equipment, shorter set-up times, less scrap produced, less costly design changes and less problems with variability in steel sheet properties or thickness.

As a general guide in deciding whether it is more economical to spin or deep draw, the following formulae can be used first by inserting the spinning data and then the deep drawing data:

$$P = M + L + T$$

$$t = B + \frac{N}{R}$$

where P = cost per part
M = material cost per part
L = labour cost per part
T = tool cost per part

t = time to produce the part, hours
B = time to build the tools, hours
N = total number of parts
R = production rate of parts, per hour

Production costs are generally proportional to the production volume so small batches are favoured. But as the size and complexity of the part increase the economical volume of parts which can be formed by spinning or flow turning increases and with the development of automatic spinning the practical range for spinning has been extended even further.

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