METAL SPINNING ADAPTED TO THE SCHOOL SHOP

by

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INTRODUCTION

By definition, metal spinning is the procedure of making sheet metal disks into hollow shapes by pressing a tool against a rotating form or spinning chuck. It is one of the oldest of metalworking arts and has been used in making circular hollow ware for many years. It is thought that the art originated with the Chinese as far back as the year 900 A. D. However, most of our present day knowledge of the art has come from the Romans and the Greeks (18).

During the reign of King Edward III metal spinning was introduced as a trade in Europe. The workmen jealously guarded their trade, and set up their own trade guilds to protect the craft against inferior workmanship. An apprenticeship of seven years was required of the youths who started at the age of fourteen or fifteen. They were required to serve a year before being allowed to use any of the spinning tools.

Metal spinning in the United States was first introduced by a man named Jordon in 1840, according to Regan and Smith (32). He started a small shop in New York City and taught the trade to several apprentices. In the early years that followed, spinning was used exclusively for production of fine gold, silver, and pewter hollow ware and chalices. Chandelier parts and cooking utensils were being made by this process at the end of the century. As late as World War I only soft non-ferrous metals were formed by this art (51). Since about 1920 and especially during World War II, great strides have been made in metal spinning and its application has been broadened considerably.

Today there are many companies turning out a great variety of spun products for the commercial world. Other companies have shops where metal spinning is done as a side line to their real business. Still others are using metal spinning in conjunction with drawing operations. Spinning may precede or be subsequent to the drawing operation; or complex shapes may be handled by fabricating a combination of spun parts with deep drawn sections.

Though metal spinning has been replaced in many cases by drawing and stamping operations, it can never be supplanted entirely. As in other metalworking industries, the horizon of metal spinning is continually expanding. Jobs considered impossible a few years ago are now everyday occurrences in metal spinning.

It is reasonable to conclude that this phase of metalworking lends itself to educational values in the school and to the recreational aspects in the home workshop. The interest appeal and fascination insures enthusiasm in the beginning student. The possibilities for finding projects are almost unlimited, and spinning offers an opportunity to produce articles of real artistic value.

A great number of industrial arts instructors wish to know more about metal spinning, thus enabling them to add a new educational activity to their school shop. The purpose of this thesis was to study metal spinning and see how it could be adapted as a unit in the industrial arts shop.

REVIEW OF LITERATURE

Metal spinning is not a new idea in schools, for as far back as 1898 this phase of metal work was done in India in the Madras School of Arts (32). But it is new in the schools of United States and only a relatively few schools in industrial areas have a unit of metal spinning in their shops. This situation is believed by the author to be partly due to a lack of information. Metal spinning has from its origin been kept in the hands of a few craftsmen who have closely guarded the secrets of their trade.

After a thorough survey of the library facilities and book publishers, only five books were found containing useful information. Of the five books, only two were completely devoted to metal spinning.

A large amount of information was found in periodicals and through phamplets supplied by different manufacturers, but much of this information was devoted to commercial methods and techniques.

It is impossible to set definite limitations to the application of metal spinning. The potential uses for this method of forming sheet metal are almost limitless. One manufacturer of spun products (27) has recently designed and built an automatic spinning lathe. The unit has a cycle similar to that of a full battery of drawing presses and is applicable to many conical shapes. This manufacturer has handled jobs exceeding a million pieces on this automatic equipment. For instance, stainless steels, type 430 and 446, are automatically formed into truncated cones used for television picture tubes in twelve seconds. A blank one-eighth inch thick is drawn to a depth of 14 inches at an angle of 24 degrees. Side wall tolerance is held to a plus or minus 0.005 inch and the inside surface of the cone is completely free of all blemishes.

Another interesting application of metal spinning comes from Sullivan (49) in saying

> About two years ago engineers at the El Segundo plant of Douglas Aircraft Company formulated a plan to spin flat metal sheets into neutral shapes prior to drop hammer forming. During this prespinning process, the sheets could be given a shape approaching that of the finished part with the net result that several sets of staging dies could be eliminated during final forming. Furthermore, during this prespinning, metal thickness and distribution could be controlled to minimize excessive local thinning and rupture during final hammer forming. Today, dozens of hammer-formed parts used in the company's production of airplanes.... are transition stamped from neutral shapes spun prior to hammer forming.

Prior to prespinning, a small microswitch box required nine sets of drop hammer staging dies to form it in an acceptable manner. Despite this number of dies, many boxes were broken or ruptured during forming due to the deep draw involved.

The many variations in shapes, materials, thickness, size, and quantity of an individual product sometimes make selection of the best method of processing difficult to determine. Some of these factors that concern metal spinning will be discussed in detail later.

EQUIPMENT

Lathes

Spinning lathes used in industry may vary in general design from simple machines to elaborate ones such as the automatic lathe previously described. Special machines, similar in general design to boring mills, are used for spinning large, heavy work by mechanical means.

Most of the modern engine lathes or heavy duty wood lathes are excellent for the school shop as they can be adapted to metal spinning with little expense. Many of the lathe manufacturers now incorporate ball or tapered roller bearings in their better lathes to carry thrust and radial loads.

The lathe in any case must be heavy and rigid in design. Due to the heavy end thrust on the spindle bearings during the spinning process, it is important to have a lathe which is equipped with thrust bearings. The lathe should be equipped for variable speeds. Speeds should range from about 600 to 1800 revolutions per minute with at least four speed steps. Although some commercial work is done at speeds of 2400 revolutions per minute, this speed is not important or desirable for spinning in the school shop where production speed and experience are not factors. The only use for such high speed on a school shop lathe would be for polishing the spun project, and this may be accomplished at lower speeds. The lathe should also have a large enough motor to deliver a constant flow of power. Considerable friction and pressure are developed in the spinning operation. A minimum of a one-half horsepower motor is the smallest recommended by the author for best results.

Where cost is not an important factor, the school shop can be equipped with lathes designed specifically for metal spinning. Depending on lathe design, wood turning or metal turning may also be done on spinning lathes. An important feature of many of these lathes is the incorporation of a gap in the bed near the headstock. This feature is very desirable because all spinning must be done over the bed, and the original disc for a deep drawn article is of much larger diameter than the finished article. Therefore, these lathes allow a larger disc diameter to be spun than is possible with the conventional straight bed lathes.

Letters of inquiry were written to various manufacturers of spinning equipment. An abundant supply of literature was received from six large and well known companies. This literature included various blueprints of spinning lathes, specifications, lathe accessories, tools, and prices. It is reasonable to conclude that the buyer for a school shop has a large field from which he may select his spinning equipment.

Spinning Centers

The spinning center is probably the most important part of the mechanical set-up necessary in transforming any lathe for metal spinning. It is absolutely necessary, for successful spinning, to have a rotating tail stock or back center (32). Various types may be purchased which, in general, consist of a hollow steel cylinder in which a steel shaft rotates against radial and thrust ball or roller bearings. The outer end of the shaft which rotates is either turned to an angle of about 60 degrees, or may be hollow for attaching a follow block. The other end of the spinning center is equipped with a tapered shank that fits the lathe tail stock.

When a metal turning lathe is available, an excellent spinning center can be made that will last indefinitely. The one shown in Plate I was designed and built by the author around a Timken tapered roller bearing. Other bearings of this type, such as front wheel thrust bearingsfrom automobiles may be used. Dimensions were omitted from the drawing because they will depend on various factors, such as the size and type of bearing used and type of taper in the lathe tail stock. Details of making this center will be found under experimental procedures.

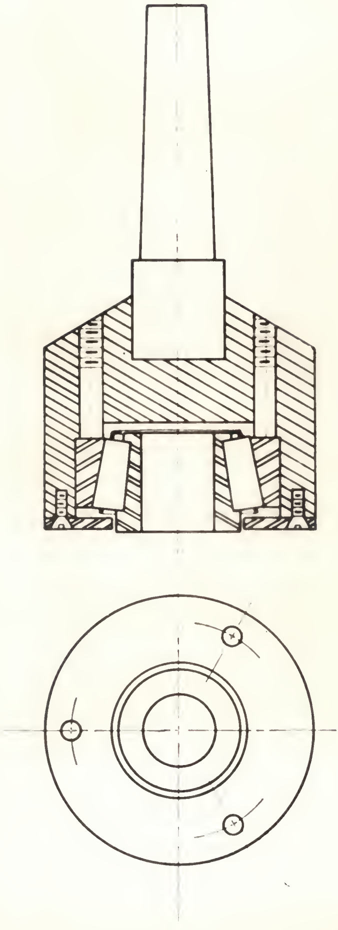
Follow Blocks

The follow block, sometimes called the follower or friction block, is a simple fixture used to hold the metal blank against the chuck or form over which the metal is to be spun. It must rotate freely and at the same speed of the chuck. Any slippage will cause chatter and burn the wood. Some authorities (22) recommend serrating the face of the block. Others (18) recommend rosin, but in any case the face of the block should fit the base of the object to be spun. The block may have a pin set in its center to fit a corresponding hole in the chuck if it is permissible to drill the metal blank. Usually, followers are made about one-fourth inch smaller in diameter than the corresponding surface of the chuck against which they seat. When the follow block is too small the metal will spin back over it

EXPLANATION OF PLATE I

A drawing of the spinning center made around a Timken roller bearing

PLATE I



and spoil the project. If the follow block is too large, it would be impossible to work in close to the base of the object being spun.

Spinning Rests

The principle of the spinning rest, shown in Plate II, is practically the same as that of a tool rest on a wood lathe except that vertical holes are drilled in it at intervals for holding a steel pin. The pin acts as a fulcrum for the spinning tool. The pin has a shoulder so it will not drop through the holes. The fit must be free so that the pin may be moved easily from hole to hole as the spinning progresses toward the head of the lathe. The rest may be purchased at a nominal cost or may easily be made from stock found around the metal shop.

One inch square bar stock may be used for the horizontal portion of the rest. Three-eights inch holes are drilled vertically at equally spaced intervals to accept the fulcrum pin. The post of the rest should be turned to fit the toolrest holder of the lathe to be used for spinning. The post and horizontal piece may be assembled by brazing or welding after drilling a hole in the underside of the horizontal piece to accept the post. The fulcrum pin may be made from one-half inch round stock. A step about one inch long with a free fit is turned to go in the holes previously drilled in the horizontal portion of the rest.

Spinning Tools

The shape, size, finish and material used for spinning tools play an important part in the quality of the finished project. Because of the lack of standardization as to size and dimensions, the experienced spinner

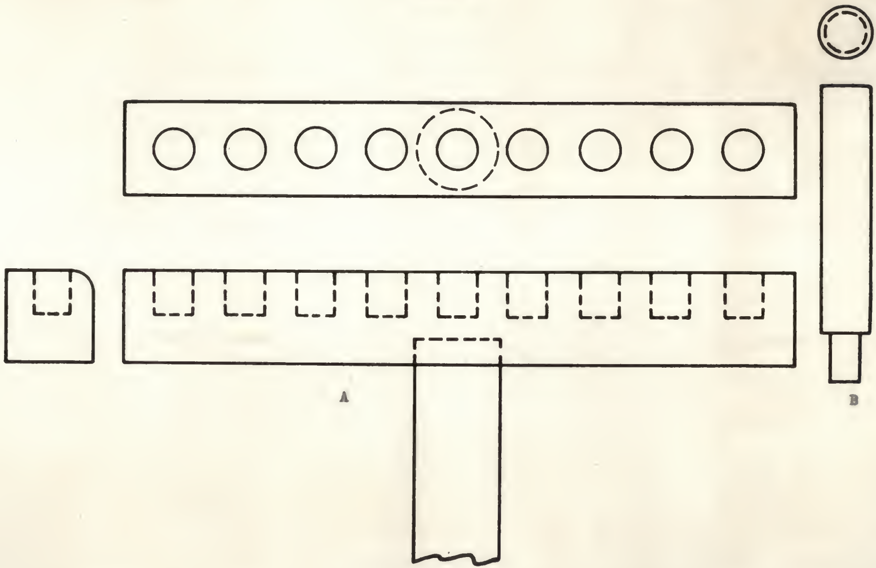
EXPLANATION OF PLATE II

A drawing of a typical spinning rest and fulcrum pin

A. Spinning rest

B. Fulcrum pin

PLATE II



will make his own tools to conform to the requirements of the work and to his personal ideas. All spinning tools may be placed in three general classes: blunt tools, beading tools, and cutting tools (58).

Some manufacturers have standardized on a small set, and these are usually sufficient for the school shop. If others are desirable, they may be forged to the desired shape out of drill rod or other high carbon steel. After forging, the tools must be hand ground, hardened, and polished on the contact surface to a mirrorlike finish. Such a finish is necessary to prevent abrading and scratching the sheet metal. Hickory, hard maple, or ash may also be used as tool material for "breaking down" or forming soft metal blanks such as pewter and aluminum. Plate III shows the set of tools used by the author. They were all hand made.

The blunt tools are the most numerous in shapes and kinds. Their general use is for breaking down the metal blank prior to finish forming. The flat tool is used more than any of the others. This all purpose tool has one flat side which is used for smoothing and planishing after the forming process. The other side is rounded and used for breaking down soft metals. The edges between the flat and round sides have a sharp radius for working small fillets and corners. Other tools commonly found in this class are the point and ball tools. The point tool may be used for spinning the disc to the chuck at the beginning, and also for bearing into curves of small radii. The ball tool is generally used on the harder metals. It should never be used to spin the metal snug to the chuck.

A backstick may be made from a broomstick or large dowel rod. It is shaped to a chisel point similar to that of a blunt cold chisel. The chief function of the backstick is to provide pressure behind the spinning tool in the forming process so as to prevent the metal blank from buckling.

EXPLANATION OF PLATE III

The set of hand made spinning tools that were used for spinning

A. Beading tool

B. Cutting tool

C. Diamond point cutting tool

D. Ball pointed tool

E. Backstick

F. Tongue tool

G. Pointed tool

H. Flat tool

I. Round point tool

J. Round point tool

K. Round point tool

L. Round point tool

M. Ball point tool

N. Ball point tool

O. Ball point tool

P. Oval point tool

Q. Round point tool

PLATE III

A B C D E F G H I J K L M N O P Q

Beading tools are used to turn the edge of the metal into a lip, or completely over into a true bead. They may also be used as a double grooving tool to scribe parallel lines and add a decorative motif to goblets, cups, and other articles. Most of these tools are made with a concave roller similar to that of a small pulley. Interchangeable rolls of various sizes may be purchased. Beads may also be made without a beading roll when the spinner has gained some experience.

The cutting tools are designed to trim excess metal from the spun object and for rounding of sharp edges. The most common one is the diamond point ground from square stock. Flat chisels and tools ground similar to metal turning bits are also used.

Chucks

Spinning chucks are the forms to which the metal is spun. They may be made of close grained hardwoods or metal. Maple, birch, or gum are suitable woods; although hard maple is preferable to the others (18). Soft woods mar easily and often leave grain marks on the spun article. Metal chucks are used when there is a large number of articles to be spun. Their use permits a smoother finish on the article than is possible with wooden chucks.

Intermediate or breakdown chucks are necessary for most deep spun articles. They consist of a series of chucks, the shape of each progressing toward the finished size of the article. They are necessary to prevent the metal disc from buckling. The number used depends on the skill of the spinner and the depth of the draw.

Sectional chucks are used to produce shapes having re-entrant contours in which the neck or opening is smaller than the body of the spun article.

They must be carefully made and well matched at the joints to prevent section marks from showing on the finished project. They must be designed so that the largest piece may be withdrawn through the smallest diameter after the object is spun. Sectional chucks consist of a core around which a number of segments are placed that conform to the shape to be spun. The segments are keyed at the front of the chuck by a recess in the core, and at the back by a circular collar.

There are several methods of attaching chucks to the lathe spindle. Faceplates may be used, although this method has the disadvantage of not being able to remove the face plate for other uses until the chuck is to be discarded. Dies may be purchased to thread a hole in the wooden chuck so it may be screwed directly to the lathe spindle. This procedure is satisfactory for the school shop where the chucks are relatively small. Another method is to place a threaded metal plug in a cavity at the back of the chuck, after which a lead alloy is poured around the thread. When solidification takes place, the plug is backed out, thus forming a cast thread which is screwed to the spindle. The chuck is then turned to size.

MATERIALS AND ENGINEERING FACTORS

Lubricants

Friction, resulting from the application of pressure with the spinning tool against the metal being spun, generates considerable heat. To reduce this heat and to keep the tools from abrading the metal, a lubricant must be used on the disc while it is being spun. The principal merits of a lubricant are the ability to adhere to the metal surface and easy cleanability. Consistency is important as heavy lubricants fly off in chunks and ball-up under the spinning tool (11). Light lubricants will fly off in a spray as they have inadequate body.

Lubricants vary with the metal used, and many mixtures of various components have been tried. There are some commercial lubricants on the market made especially for spinning. Many spinning manufacturers make their own lubricants to suit their personal preference. The more common varieties and their applications are discussed below.

Tallow, heavy grease, lard oil, beeswax, paraffin, laundry soap, or various combinations of these form the basic lubricants for spinning aluminum and copper alloys. Care must be exercised to use an alkali free soap on aluminum when a high finish is desired as the alkali will etch the surface.

Tallow, soap, and oil mixtures are used on pewter spinnings. Laundry soap or a mixture of paraffin and tallow is the usual lubricant for magnesium alloys, except when spinning at high temperatures. In such instances, a graphite and tallow mixture or a graphite suspension in carbon tetrachloride is applied. In deep spinnings of magnesium the lubricant must withstand temperatures as high as 700 degrees Fahrenheit (16).

When spinning lead, zinc, silver and gold a tallow candle is usually employed as the lubricant. Lubricants for shallow spun articles of stainless steel and steel are laundry soap, tallow, or a soap suspension in oil. For large and heavy spun articles a lubricant such as those mentioned for hot spinning magnesium must be employed.

Metals

The range of metals which can be spun has been expanded considerably through improvement in tools, equipment and techniques. In general, any metal with deep drawing characteristics is ideal for spinning. Metals not having deep drawing properties may be successfully spun when properly annealed or heated while being spun. Metals with rapid work hardening properties will have to be annealed at various stages if the spinning is severe, as the spinning process is similar to a long series of drawing operations.

Many metals are not adaptable to school shop spinning. As an example, magnesium cannot be formed to any extent at room temperatures, but when heated to a temperature range of 400 to 600 degrees Fahrenheit, it may be formed to a greater extent than most other metals (37). Heavy gage steel and other stiff metals require too much pressure for forming to be of value in the school shop. Because of their ductility, aluminum, pewter, copper and brass are probably the most suitable materials for the school shop.

One of the largest manufacturers of spun products had done considerable research on the adaptability of metals to spinning (27). Table 1 shows the "spinability" of various metals with a unit of 1.00 given to the type of material which lends itself most readily to forming by the cold metal spinning process. The lower the percentage figure, the more difficult it is to form a particular metal.

The following figures may vary somewhat depending on circumstances such as contour of the article, gage, and size.

Table 1. Adaptability of metals to spinning.

Type of metal	Shallow spinning	Deep spinning
Aluminum and the alloys		
2SO	1.00	1.00
3SO	1.00	.99
24SO	.65	.45
52SO	.80	.55
61SO	.90	.80
Copper and the alloys		
Copper - cold rolled	1.00	1.00
Copper - hot rolled	.99	.88
Yellow brass	.99	.92
Low brass	.96	.89
Red brass	.90	.83
Commercial bronze	.88	.80
Gilding metal	.85	.75
Admirality brass	.82	.70
Naval brass	.75	.45
Muntz metal	.55	.30
Phosphor bronze Z	.85	.40
Phosphor bronze C	.85	.45
Cupro nickel 70-30	.95	.65
Silicon bronze	.94	.60
Common steels S.A.E.-1020-15-20 and miscellaneous steels		
Cold rolled deep drawing quality	1.00	1.00
Vitreous enameling, deep drawing	1.00	.95
Standard cold rolled	1.00	.92
Hot rolled pickled and oiled	1.00	.92
Hot rolled low carbon	.90	.55
Hot rolled copper bearing	.88	.51
Lead coated	1.00	Impractical
Galvannealed	1.00	Impractical
Galvanized	.90	Impractical
High tensile steels	.45	.15
.40 and up of carbon	.25	.10
Stainless steels		
302 18-8	.98	.60
304 18-8	.98	.90
305 18-11 Free spinning	1.00	1.00
309S 25-12	.80	.45
316 18-8 Molybdenum	.90	.60
321 18-8 Titenium	.85	.50
347 18-8 Columbium	.90	.50
430 17 Chromium	.90	.50

Table 1 (concl.)

Type of metal	Shallow spinning	Deep spinning
Nickel and nickel alloys		
Monel-spinning quality	1.00	.90
Monel-special cold rolled soft temper	1.00	.85
Inconel	.90	.70
"L" Nickel	1.00	1.00
Nickel	1.00	.92
Multimet N-155	.90	.50
Hastelloy A	.90	.50
Hastelloy B	.70	.30
Hastelloy C	.50	.10
Miscellaneous		
Lead	.96	.90
Pewter	1.00	.90
Zinc	1.00	1.00
Tantalum	.86	.45
Magnesium*	.80	.45
Molybdenum*	.55	.15

*These two metals, for all practical purposes, must be hot spun.

Summary

The following is a comparison of the best metal in each of the six groups.

Aluminum 2SO	1.00
Zinc	.94
Steel, cold rolled deep drawing quality	.91
Copper, cold rolled annealed	.87
Nickel	.86
Stainless steel type 305	.70

Gages and Tolerances

It is difficult, if not impossible, to state specifically the maximum gage limits that can be spun. One company (53) has successfully spun steel heads for pressure vessels as thick as six inches. These heads were heated to around 2000 degrees Fahrenheit, and pressure on the forming rolls ran up to 166 tons.

Generally speaking, simple shapes can readily be spun in aluminum in thicknesses up to one-half inch (52).

Other soft metals, such as copper and copper alloys, may be economically spun with deep contours up to one-fourth inch. Spinning may be accomplished in low carbon steels up to three-sixteenths inch in thickness (7), cold rolled steel up to five-thirty-seconds inch, stainless steel up to one-eighth inch, and nickel alloys up to five sixty-fourths inch.

Tolerances are largely dependent on the skill of the operator, the size and material of the spun article, and the chuck material. Standard limits for maximum spinning economy generally run a plus or minus one-eighth inch for diameters beyond 36 inches, one-sixteenth inch for diameters from 18 to 36 inches, and one-thirty second inch for diameters under 18 inches. Where cost warrants, tolerances of a plus or minus .005 inch have been accomplished on steel chucks (43).

Size and Design

Sizes of projected spinnings have ranged in diameters from one-fourth inch to 250 inches (53, 21). The only limit to diameters that can be spun in the school shop is the swing of the lathe.

No set mathematical formula can be stated for determining the blank size for a given article as the design of the form determines the size. One method is to take the radius of the base plus the depth of the chuck, and use the sum as the radius of the blank. Another method is to use the sum of the largest diameter and the height (18). However, these methods are only estimates, the final blank size being determined by trial and error. In any case, the blank should be large enough to allow the edges to be trimmed after spinning.

Since the metal is formed over a chuck rotating in a lathe, the process is limited to symmetrical articles that are circular in cross section normal to the axis of rotation. These articles may be straight cylinders with the same diameter throughout, cones, hemispheres, partial circles or any segment of a circle. Concentric details may also be spun into any part of a rectangular sheet.

Spinning is also applicable to metals other than those whose surface is solid or unbroken. Special techniques have made it practical and economical to spin shapes of perforated and expanded metal. The holes or mesh are elongated according to the article's contour changes. However, these distortions are usually without significance to the product's end use.

Many of the important factors incident to good spinning design closely parallel those for stampings and deep drawn parts. These important factors include material thickness, depth of spinning, bend radii, diameter, steps in diameter, and workability of the metal.

Minimum permissible thickness of the finished part must be considered because, just as in rolling or drawing, the metal is subjected to considerable deformation. Reduction in thickness up to thirty percent (35) may occur on deep spun articles. Skilled operators can control much of this metal distribution; and, in soft metals, may even finish with a portion thicker than that of the starting gage.

The three basic shapes that are successfully spun are shown in Plate IV, Fig. 1. The cone is the easiest and most economical form to shape by spinning as the metal meets the chuck at easy angles. Even when worked down to severe depths, the metal is not subject to severe strains. The hemisphere is more difficult to spin as the angles grow increasingly sharper as the metal is spun down. The hardest shape to produce is the straight sided cylinder. Sharper angles encountered during the spindown puts the metal under greater strain, and for this reason more time and greater operator skill is needed. Diameter and length of cylinders must be balanced with the metal gage to assure minimum wall thickness variation (7).

Streamlined or smooth curves and large radii are an aid to manufacture and appearance. Stepped sections can be more easily produced if conical steps with large radii are designed in the article to be spun. Plate IV, Figs. 2 and 3 show other points of design that may simplify the spinning of an article.

Other Considerations for Production

In the past, metal spinning was considered as a method of production of small quantities where drawing dies would make the unit cost prohibitive. Today, however, with the advent of mechanical and automatic spinning lathes, each product or part must be studied individually before definite conclusions may be drawn. Spinning has been proved to apply to programs involving over a million duplicate pieces.

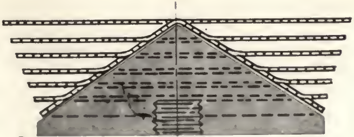
EXPLANATION OF PLATE IV

Fig. 1. Three basic shapes that are successfully spun. The cone is the easiest to spin, the hemisphere next, and the cylinder is the most difficult.

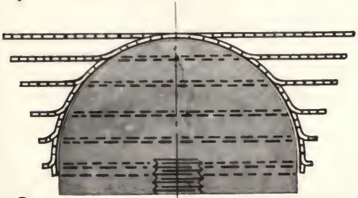
Fig. 2. Points of design that should be considered in metal spinning.

Fig. 3. Points of design concerning a beaded edge on the finished article.

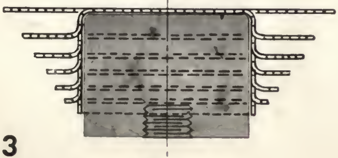
PLATE IV



1

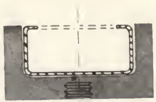


2

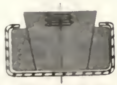


3

Fig. 1



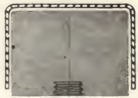
1 An extra hollow block is necessary in forming an inside flange. This is sufficient tooling if very liberal depth and diameter tolerances can be allowed.



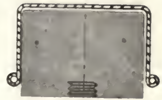
2 If the flange must be spun to exacting tolerance, an expensive collapsible split block is inserted for the flanging operation.

3 This top view of part of a collapsible block shows how the sections are removed from the finished cylinder.

Fig. 2



1 A sheet of metal is spun over a standard block.



2 An outside bead can be added to this shape with a beading tool. No change in the original block is required.

3 An inside bead requires another block, a hollow block, to prevent bellying of cylinder edges during beading. The extra operation involves additional time and costs.

Fig. 3

Tool cost is low in spinning as the forms can be made of wood or soft metal. Those forms can be made much quicker than draw tools, and production can start earlier. The rapidity with which a specification can be converted into a finished part is often one of the chief economies.

Spinning also has advantages in experimental and development uses. Changes in design can be made quickly and at low cost by reworking wood or soft metal tools instead of hardened steel dies. Larger shapes than practical with other manufacturing methods can be made on spinning lathes of suitable swing.

METHODS AND TECHNIQUES

The Spinning Process

When starting the spinning process, the chuck should be screwed firmly to the lathe spindle and turned to the inside dimensions of the article to be spun. The chuck should be carefully sanded to remove all tool marks. The metal blank is then centered between the chuck and the follow block, after which a suitable lubricant is applied to the blank as the lathe turns at a slow speed. A tool is then applied near the base of the blank to seat it on the chuck which prevents it from flying out of the lathe. The operator should not stand in line with the blank before it is seated to the chuck.

The tool rest is placed perpendicular to and about two inches from the edge of the blank so the tool will make contact below the horizontal center line of the blank. The fulcrum pin is placed just to the right of the blank and, as the spinning progresses, it is moved to another hole to give the tool better leverage.

Experience is the only guide for telling the spinner exactly how and where to apply the tool, and what tool to use. If too much pressure is applied to the blank, the disc will wrinkle or the tool will break through the metal. If wrinkles do occur the lathe should be stopped, and the wrinkles hammered out before proceeding.

Wrinkling can usually be prevented by not exerting too much pressure with the spinning tool. The possibility of wrinkling may be reduced by holding the backstick in the operator's left hand on the left side of the disc exactly opposite the point of contact of the spinning tool and drawing it to the outer edge of the disc as the point of the spinner's tool is moved in that direction.

The actual work in metal spinning is done by motions of the entire body. The handle of the tool should be placed under the right arm next to the body. Steady the tool against the rest by grasping the fulcrum pin with the fingers of the left hand. The metal is worked up from the bottom toward the outer edge of the blank in a series of long and short sweeps, semi-circular in direction. The long sweep moves a band of metal toward the chuck, and the short sweeps lay part of that band down on the chuck. This cycle is repeated until the shell is completely spun. It is essential that the spinner overlap each step in the procedure so as to produce smooth contours. Another important point is to avoid working the tool continuously in one direction. The outward sweep tends to reduce the metal in thickness, and the return sweep tends to build it up again.

Methods of Forming

The beginning student should rely on simple forms of a shallow nature for successful spinnings. After a little experience is gained, a great variety of applications may be used. Deep drawn articles may be produced over a solid chuck with the use of intermediate breakdown forms. Articles with re-entrant curves may be produced over sectional chucks or possibly parts of an article may be spun in air. "Spinning in air" is a term used when the metal is formed without any chuck to support it, and some is done in the forming of all spinnings.

In articles such as lamp stems and bases, the metal may be spun down permanently over the wooden chuck. Another method of handling re-entrant curves in industrial spinning is by using internal rolls that form the metal from inside the shell. Other unique methods of forming will be found where the situation warrants. For instance, a float used in hydraulic car lifts (19) has been successfully spun by placing a hemispherical shaped tool in a drill press. Magnesium tubing was closed on the ends by bringing the rotating tool down against the stationary tubing. The heat produced was helpful in forming the magnesium.

Annealing

The metal blank should be in a fully annealed condition prior to spinning. Due to the work hardening characteristics of some metals, they may require annealing at various stages in the spinning process. When to anneal can only be determined by experience. The spinner will quickly learn the "feel" of the metal against the tool, and when the metal refuses to respond to normal pressures the shell should be removed and annealed.

The work hardening ability of some metals may be used to an advantage when it is desirable for the finished article to be more rigid than in the annealed condition. By controlling the final anneal prior to the final spinning down against the chuck, the article may be cold worked so as to produce the desirable stiffness. Stresses remaining in the finished article are usually negligible.

Annealing temperatures may be obtained from handbooks. Where these temperatures cannot be accurately controlled, as in the usual school shop, other methods will have to be relied upon. The most common method is color changes such as a very dull red for copper and a bright cherry red for steel. Brass had no appreciable color change at annealing temperatures. A good plan is to cover the blank with oil prior to heating. When the oil burns off, the brass should have a very dull red color and at the annealing temperature.

Aluminum does not have any color change when heated. 2S aluminum does not work harden to any extent and therefore requires no annealing. Pewter is another metal in this class. Other aluminums such as 3S, 52S, and 24S may require annealing. This can be successfully accomplished for school shop purposes by heating until a white pine splinter will char on the metal's surface.

Spinning Speeds

The speed of the spinning lathe depends on the diameter and thickness of the blank, as well as the type and temper of the metal being spun. Steel requires slow speeds and high pressures; brass and aluminum can be spun with higher speeds and low pressures. Normally, as the blank diameter increases, the lathe speed should be reduced.

One company (28) kept accurate records over an extended period of time of every spinning job performed. Data were obtained on the diameter and thickness of the blank, and the speed used. From this case history a chart was constructed, Plate V, showing spinning speeds in relation to gage thickness and diameter for five different metals. It was also found that speeds, like notes in music, seemed to have harmonies. Actually, there appeared to be several speed ranges for the same piece of metal of the same thickness and diameter. However, and this leads to one of the metal spinner's trade secrets, there appeared to be a best speed for each metal when measured in terms of standard operation.

EXPERIMENTAL PROCEDURE

Lathe and Lathe Accessories

A regular wood lathe with a thrust bearing in the headstock was chosen and adapted for metal spinning. It was manufactured by J. G. Blount Company, Everett, Massachusetts; and had a twelve inch swing with a forty inch bed. The direct drive one-half horsepower motor provided speeds of 560, 1140, 1727 and 3540 revolutions per minute at full load.

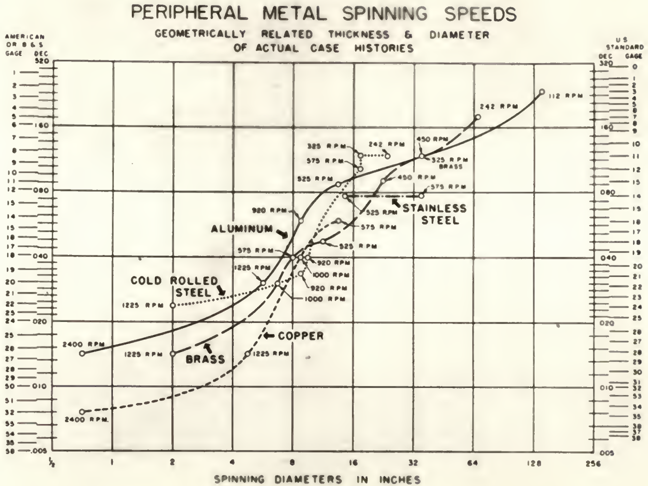
The spinning center, Plate I, was made by press fitting a number two Morse taper shank into a cast iron base. The base and shank were then brazed together and turned as a unit by inserting the shank into the spindle of a metal turning lathe. This method assured proper alignment of the shank and bearing. The front part of the base was then faced and bored out to accept the cup of the bearing with a press fit. The hole was bored deeper at a smaller diameter to afford end clearance for the bearing cone.

The cover plate was attached by tapping the base with three equally spaced holes, and fastening it with countersunk machine screws. It was then turned to the proper dimensions. Care was exercised to obtain enough

EXPLANATION OF PLATE V

A chart showing lathe speeds for metal spinning in relation to gage thickness and blank size

PLATE V


PERIPHERAL METAL SPINNING SPEEDS
GEOMETRICALLY RELATED THICKNESS & DIAMETER
OF ACTUAL CASE HISTORIES
AMERICAN OR B & S GAGE DEC
U S STANDARD DEC GAGE
ALUMINUM
COLD ROLLED STEEL
BRASS
COPPER
STAINLESS STEEL
112 RPM
242 RPM
450 RPM
325 RPM BRASS
325 RPM
575 RPM
525 RPM
920 RPM
1000 RPM
1225 RPM
2400 RPM
SPINNING DIAMETERS IN INCHES

clearance between the face of the cover plate and the face of the cone so the follow blocks would not touch the cover plate. Clearance was also necessary between the hole bored in the cover plate and the bearing cone. Before the bearing cup was pressed into place, three equally spaced holes were drilled and tapped in the back side of the base. These holes were for the purpose of inserting a drift punch when removing the cup in case the bearing should break down. The holes were tapped for insertion of set screws, which prevented the lubricant from flowing out. The center is believed to be of sound design, as it proved very satisfactory in both spinning and polishing.

Follow blocks were made by two methods. Some were made by drilling a hole about half way through the piece of wood to be used, and then inserting a piece of three-fourths inch dowel rod about one inch long. The dowel rod should make a snug fit and may be glued. The portion of the dowel rod projecting from the piece served as a pilot when inserted into the spinning center. The block was then brought up against the chuck with sufficient pressure to allow turning it down to proper size. Other follow blocks were made by turning them down on a screw center face plate. Both methods are satisfactory and take about the same amount of time.

The spinning rest that was used had been made previously for another lathe. The only alteration necessary for its use was the turning of its post to fit the tool holder in the lathe that was used.

Tools and Materials

Some of the spinning tools used had been made previous to this study. A few additional tools were made by the author by brazing various sizes of steel bearing balls on steel shanks. The balls were then normalized, hardened and polished. Care should be exercised in normalizing the balls, as the normalizing temperature is very near the melting temperature of the material used for brazing. Polishing was done with a cotton buffing wheel and jeweler's rouge. These forming tools proved very satisfactory, and the cost and time for making them was low.

A backstick, oval point tool and round nose tool was made from large dowel rods because they were available. They could have been made equally as well from other hard woods in broomsticks, baseball bats, axe handles and the like.

A cutting tool was also made from a narrow round nosed wood turning tool. The tool was ground very similar to a metal cutting bit used in a metal lathe. The nose was ground very narrow and contained some top rake. This tool was more efficient in cutting and trimming edges than the diamond pointed tool, although more care had to be exercised to prevent it from digging into the metal.

The chucks used for spinning were made of either hard or soft maple, with one exception. Hard maple was found to be better than soft maple because it did not mar as easily. Both give good results, but hard maple is reccommended for the school shop as it will take more abuse before the chuck needs to be overhauled. The exception was one chuck made from fir to determine the extent of grain impressions it would leave on an aluminum shell. The results indicated that fir should never be used as chuck material for the final spin if a smooth finish is desired. Very deep grain impressions were left on the surface of the aluminum even when tool pressures were very light.

Yellow laundry soap, paraffin and heavy grease were tried as lubricants. Using moderate speeds, the grease had a tendency to fly off in a spray due to the heat developed in the shell from the forming process. Paraffin proved satisfactory, but more frequent applications were necessary than either grease or soap. Paraffin also had a slight tendency to fly off when heat was developed in the shell. Soap was found to be the best of the lubricants tried. It provided sufficient lubrication and was the easiest to remove.

Aluminum, copper, pewter and gar-alloy were the metals used for spinning. All aluminum spinnings were made from .036 inch utility sheet. This aluminum was checked for copper content with a sodium hydroxide etchant and no appreciable amount of copper was found. Gar-alloy is a zinc based alloy containing copper and silver. It has a grayish finish that is darker than pewter. It anneals at 270 degrees Fahrenheit.

Methods and Techniques

Letters were written at the outset of this problem to three nearby metal spinning firms for permission to visit their metal spinning department. It was thought that much could be learned from observing methods and techniques of experienced spinners. All firms replied that defense contracts were being filled, and permission for an inspection trip could not be granted. Therefore, the author had to rely on available printed material for information.

All work was conducted under conditions found in the typical high school industrial arts shops. Electric furnaces for maintaining correct annealing temperatures were available, but not used because such furnaces are not found in the average school shop. All annealing was satisfactorily accomplished by visual methods previously explained.

Aluminum was chosen for the major metal used in experimentation because of its availability, low cost and good spinning characteristics. Shallow spun articles such as the coaster and ash tray, Plate VI, were spun first. After a little experience was gained, deeper spun articles such as the funnel and bowl were accomplished.

It was found that wrinkling of the metal, Plate VII, is the greatest trouble encountered by the beginning spinner. Wrinkling can be caused by trying to compress the metal near the outside edge of the blank, or by trying to work the metal too rapidly. The slightest wrinkle can be detected by the noise produced by the tool going over it. Small wrinkles can be smoothed out by working the tool in small arcs at the source of the wrinkle. Large wrinkles must be hammered out. The blank should be annealed before further spinning is attempted. If the blank is not annealed it will have a tendency to wrinkle again in the same place.

One author (38) suggested fastening the metal blank to a chuck by the use of a wood screw where design permitted a hole in the center of the spun article. This method was tried several times in the spinning of funnels, and proved unsuccessful in every case, Plate VII. The application of the forming tool acts in such a way that the radius of the disc becomes a lever with the fulcrum point at the place where the metal is fastened. In each case the force of the tool cold worked the area around the screw head to the fracture point.

A method of centering the disc recommended by almost all authorities is not considered by this author to be the best for the school shop. This method of centering consists of placing the disc between the chuck and set the follow block against it with just enough pressure to hold the disc in place. A piece of wood is then placed between the tool rest and brought

EXPLANATION OF PLATE VI

Projects made from aluminum, copper and pewter showing both shallow and deep spinnings

PLATE VI

EXPLANATION OF PLATE VII

The sample at the left shows the rupture caused by excessive cold working around the head of a screw that fastened the blank to the chuck. The other two examples depict wrinkling caused by trying to compress the metal or working it too rapidly.

PLATE VII

to bear on the edge of the disc. The lathe is started at a low speed, and the tail stock is slightly loosened so that the metal will respond to the touch of the wood. The blank is then supposed to center itself and the tail stock is quickly tightened. This method was tried, and practice was necessary before it was mastered as the disc has a tendency to get farther out of center if the correct pressure is not applied. The disc may be satisfactorily centered by shifting the disc as the lathe is turned by hand. This method insures against the disc flying out of the lathe and injuring the spinner or bystanders.

Four identical flower pots were spun out of pewter, aluminum, copper and gar-alloy. This was done to compare the spinability of these metals. Pewter and aluminum appeared to be the easiest to spin with no appreciable difference between the two metals. Copper was next difficult, and gar-alloy was the most difficult. Gar-alloy required the greatest pressures and cold worked faster than any of the others. Reduction of thickness in percent for these metals were: aluminum 23 percent, copper 20 percent, pewter 17 percent, gar-alloy 29 percent. It can be seen from these figures the importance of starting with the proper gage thickness where minimum thickness of an article is specified. Inside diameters of all four flower pots were spun within a tolerance of a plus or minus one thirty-second inch.

The planters lamp, shown in Plate VIII, gives at least three examples of different forming methods. The base was spun over a permanent chuck to add weight. The re-entrant curve in the stem between the base and bowl was spun in air. The bowl was spun in a conventional manner with the use of two breakdown chucks. The upper stem was started from a nine inch blank and spun down to a length of over nine inches. The stem required seven breakdown chucks, and the final spin was accomplished by spinning it over a

EXPLANATION OF PLATE VIII

Planters lamp made from .036 inch utility sheet aluminum

PLATE VIII

EXPLANATION OF PLATE IX

Set up used for metal spinning showing from right to left the tailstock, spinning center, follow block, metal disc, and chuck

PLATE IX

permanent wooden chuck. The re-entrant curves in the upper stem were also spun in air. All blanks were annealed prior to spinning. The upper stem was annealed again after it came off the fourth breakdown chuck.

CONCLUSIONS

Metal spinning can be adapted to the school shop. The objectives of a unit in metal spinning run parallel to other courses offered in industrial arts.

Equipping the school shop for metal spinning cannot be done without considerable thought, study and effort. The necessary equipment may be made or can be purchased from reliable manufacturers.

Before a student can spin any metal he must know the speed at which the lathe should run, how to eliminate friction, when the metal should be annealed, and what kind of tool to use for forming.

The best way to teach metal spinning is by demonstration. If the teacher must rely on written instructions, a step by step procedure should be followed.

There is no single text that is adequate for teaching metal spinning. The instructor should keep a scrapbook of literature concerning this phase of metal work.

The selection of projects that can be made in the school shop by metal spinning is almost unlimited.

The beginning student in metal spinning should start with shallow spinnings and progress to deeper spun objects.

Aluminum is probably the most suitable metal for spinning in the school shop due to its working characteristics, availability and low cost.

Pewter, copper and brass are other metals that may be formed successfully in the school shop.

A good all round thickness for aluminum, copper and brass is 20 gage (.032). A good thickness for pewter is 18 gage (.040).

Maple is probably the most desirable wood for making chucks.

A low speed was found better than too high a speed for spinning as the metal tends to stand out away from the chuck at high speeds. High speeds necessitate using heavier pressures which produce greater cold working.

The cone was the easiest shape to form by metal spinning.

When spinning objects larger than ten inches, the outer edge should be dished at the beginning of the forming process so as to stiffen it and prevent vibration or buckling. The outer edge should be in a slight reverse curve towards the follow block on small objects.

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BIBLIOGRAPHY

(1) Aircraft fabrication-bending, drawing, rolling and spinning. Scranton: International Textbook, 1943.

(2) Beal, H. S. Metal spinning projects. Industrial Arts and Vocational Education. 36:39. January, 1947.

(3) Beal, H. S. Making and holding metal spinning chucks. Industrial Arts and Vocational Education. 36:388. November, 1947.

(4) Beal, H. S. Sectional spinning chucks. Industrial Arts and Vocational Education. 37:165. April, 1948.

(5) Beal, H. S. Pewter candy dish, copper cigarette container. Industrial Arts and Vocational Education. 37:200. May, 1948.

(6) Benvie, C. F. Speed table guides metal spinners. American Machinist. 93:100-101. September 22, 1949.

(7) Boltz, R. W. Production processes...their influence on design. Machine Design. 17:113-118. August 8, 1945.

(8) Compton, Alfred G. and James H. De Groodt. Advanced metal work. New York: John Wiley and Sons, 1898.

(9) Dahlen, T. G. Teaching metal spinning in the school shop. Industrial Education. 35:79-81. November, 1933.

(10) Dexter, H. M. Metal spinning and its origin. Industrial Arts and Vocational Education. 26:370-371. November, 1937.

(11) Drawing, forming, spinning and cutting of stainless steels. Phamphlet. American Rolling Mills. Middletown, Ohio. 31 p. 1947.

(12) Drawing and spinning of aluminum alloys. Machinery. 55:170-176. May, 1949.

(13) Graichen, C. C. Pewter spinning. Industrial Education. 34:103. November, 1932.

(14) Gregg, R.
Metal spinning. Popular Mechanics. 62:952-956. December, 1943.

(15) Hardeman, L. B.
Planter lamp. Industrial Arts and Vocational Education. 38:27-29. January, 1949.

(16) Hawes, L. F.
Spinning magnesium. Iron Age. 161:72-73. February 19, 1948.

(17) Jenkins, R. H.
Craftwork spun from tin cans. Popular Science. 139:180. September, 1941.

(18) Johnson, Harold V.
32 metal spinning designs. Milwaukee: Bruce Publishing, 100 p. 1941.

(19) Law, D. C.
Magnesium tubing spun and brazed to produce a critical part. Materials and Methods. 32:65-67. November, 1950.

(20) Leighton, Harold.
Spun mint tray. Industrial Arts and Vocational Education. 30:362. October, 1941.

(21) Longbridge, John W.
How to spin metals. American Machinist. 95:145-160. March 19, 1951.

(22) Ludwig, Oswald A.
Metalwork technology and practice. Bloomington: McKnight and McKnight, 1943.

(23) May, L. A.
Metal lathe spindle speed chart. Industrial Arts and Vocational Education. 40:25. January, 1951.

(24) Manzer, E. W.
Project manual for spun bowl. Industrial Arts and Vocational Education. 40:31-23. January, 1951.

(25) Manzer, E. W.
Project manual for spun candlesticks. Industrial Arts and Vocational Education. 39:402. December, 1950.

(26) Manzer, E. W.
Spinning a pewter bowl. Industrial Arts and Vocational Education. 24:234-236. August, 1935.

(27) Metal spinning and fabrication. Phamphlet.
Spincraft Inc. Milwaukee, Wisconsin. 38 p. 1950.

(28) Metal spinning geometry. Western Machinery and Steel World.
40:94-95. June, 1949.

(29) Osburn, Burl N. and Gordon O. Wilber.
Pewter spun, wrought and cast. Scranton: International Textbook, 1938.

(30) Ottey, H. A.
Using head shapes to cut costs. Product Engineering.
20:81-85. April, 1949.

(31) Properties of heat treatable aluminum alloys for drawing and spinning. Machinery. 50:253. June, 1933.

(32) Regan, James E. and Earl E. Smith.
Metal spinning for craftsmen, instructors and students.
Milwaukee: Bruce Publishing, 1936.

(33) Reynolds, J. O.
Metal spinning with aluminum. Industrial Arts and Vocational Education. 39:330. October, 1950.

(34) Reynolds, J. O.
Four multiple purpose spinning chucks. Industrial Arts and Vocational Education. 38: 333. October, 1949.

(35) Rules for metal spinning. American Machinist. 94:133-135.
May 15, 1950.

(36) Sabo, Charles.
Spinning head sends spinning costs spinning. American Machinist. 95:108-109. June 25, 1951.

(37) Schneider, Robert J.
The practical aspects of metal spinning. Iron Age.
161:76-80. February 12, 1948.

(38) Sheppard, I. A.
Metal spinning. Modern Metals. 4:28-29.
February, 1948.

(39) Smith, Earl E. and James E. Regan.
Lead cast threads for metal spinning chucks.
Industrial Arts and Vocational Education. 30:387.
November, 1941.

(40) Smith, Earl E. and James E. Regan.
Instructional sheets in metal spinning. Industrial Education.
36:108-110. March, 1934.

(41) Smith, Robert E.
Etching, spinning, raising and tooling metal. Bloomington: McKnight and McKnight, 1951.

(42) Some facts about spinning aluminum. Modern Metals. 3:16-17. June, 1947.

(43) Spencer, L. F.
Why not spin it? Iron Age. 167:105-109. March 9, 1951.

(44) Spinning aluminum. Modern Metals. 1:8-13. November, 1945.

(45) Spinning big bombs the way a potter spins a vase. Science Illustrated. 2:94. August, 1947.

(46) Spinning looks simple...takes know how. American Machinist. 94:100-101. May, 1950.

(47) Spinning permits flexibility. Product Engineering. 21:100. February, 1950.

(48) Spinning silver. Science Illustrated. 2:94. August, 1947.

(49) Sullivan, G. F.
Industrial metal spinning. Iron Age. 150:112. July 16, 1942.

(50) You can spin it. Popular Mechanics. 77:140-143. February, 1942.

(51) Weiss, Edwin.
Metal spinning by modern methods. Machinery. 52:141-148. November, 1945.

(52) Weiss, Edwin.
The technique of metal spinning. Machinery. 53:141-147. September, 1946.

(53) Wick, C. H.
Hot spinning heavy tank heads. Machinery. 53:141-147. September, 1946.

(54) Woolsey, Herbert.
Hints on difficult metal spinning. Popular Science. 123:82. July, 1933.

(55) Woolsey, Herbert.
How to spin a hollow metal sphere. Popular Science. 122:69. May, 1933.

(56) Woolsey, Herbert.
Non-tipping ash tray spun like magic from sheet metal. Popular Science. 122:76-77. April, 1933.

(57) Woolsey, Herbert.
Spinning metal with sectional chucks. Popular Science. 122:76-77. June, 1933.

(58) Woolsey, Herbert.
There's no mystery about metal spinning. Popular Science. 122:64-65. March, 1933.

METAL SPINNING ADAPTED
TO THE SCHOOL SHOP

by

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A study of the old, but not widely known art of metal spinning was conducted to determine its adaptability to the school industrial arts shop. After a review of the relatively small amount of literature available concerning this phase of metal work in the schools, a regular wood turning lathe was equipped for metal spinning. All lathe accessories and tools needed were successfully hand made. Where cost is not a factor, tools and equipment for metal spinning can be purchased from reliable manufacturers.

All phases of this work were conducted under conditions found in the typical high school industrial arts shop. Projects were chosen which conform with the abilities of most high school students. Aluminum is recommended as the most desirable material to be used due to its excellent spinning characteristics, availability, and low cost. However, other metals may be used and successfully spun.

It was found that metal spinning lends itself to educational values in the school shop. The active instructor who is seeking a new and educational activity for his shop may find the answer in metal spinning. The cost of transforming the existing wood or metal lathes for spinning was found to be very low. Spinning tools that cannot be forged in the shop may be purchased at nominal costs.

It is believed that metal spinning has a great interest appeal for students. The selection of projects that can be made is almost unlimited, even though metal spinning is restricted to articles that are symmetrical in cross sections perpendicular to the axis of rotation.