بسم الله الرحمن الرحيم

DESIGN AND FABRICATION OF A SPINNING PROCESS FOR MANUFACTURING SPARK PLUG HOLDING CAP USED IN EFI ENGINE.

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CANDIDATES DECLARATION

It is hereby declared that this thesis or any part of it has not been submitted elsewhere for the award of any degree or diploma.

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We seek excuse for any errors that might be in this report despite our best efforts.

Syed Abu Kausar

Md. Nowshad Alam

Abstract

METAL SPINNING is a term used to describe the forming of metal into seamless, axi-symmetric shapes by a combination of rotational motion and force. Metal spinning typically involves the forming of axi-symmetric components over a rotating mandrel using rigid tools or rollers. There are three types of metal spinning techniques that are practiced: Manual (conventional) spinning, Power spinning, and Automatic spinning. These 3 techniques are described in this article. The equipment for metal spinning is based on lathe technology, with appropriate modifications for the components that are being formed. Typically, sheet preforms are employed to allow relatively low forming stresses. Metal spinning can be used to cost-effectively produce single or a small number of parts out of expensive materials, such as platinum or large quantities of components of low-cost materials, such as aluminum reflectors. In this article, the term preform is used to describe the component both before and during metal spinning; other terms that are sometimes used include work piece and starting blank. In manual spinning, a circular blank of a flat sheet, or preform, is pressed against a rotating mandrel using a rigid tool. The tool is moved either manually or hydraulically over the mandrel to form the component. The forming operation can be performed using several passes. Manual metal spinning is typically performed at room temperature. However, elevated temperature metal spinning is performed for components with thick sections or for alloys with low ductility. Manual spinning is only economical for low-volume production. Manual metal spinning. In this project, for the manufacturing of a spark plug holder a spinning process has been designed and fabricated. With the designed set up experimentation has been carried out. It has been found that the manufactured holding cap are uniform in thickness in different sections and defect free holding caps can easily be manufactured from the setup.

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CHAPTER ONE

INTRODUCTION

Metal Spinning is the process of forming three dimensional symmetrical parts from flat circles of metal. Metal spinning provides an economical alternative to stamping, casting and many other metal forming processes. A flat circular blank is mounted on the spinning lathe and with a series of roller passes, the material "flows" and is laid down onto a mandrel that is the ID profile of the desired finished part. The mandrel is typically referred to as a "Spin Chuck" and is usually made from wood or steel. Wood tooling is often used for short-run or prototype work. Steel tooling is used when tighter tolerances are required and for longer running production runs. Both wood or steel spin tooling is far less costly than the tooling required for other metal forming processes.

Many materials are candidates for metal spinning, including but not limited to:

- **Aluminum**
- **Mild Steel**
- **Stainless Steel**
- **Brass**
- **Copper**
- **Inconel**

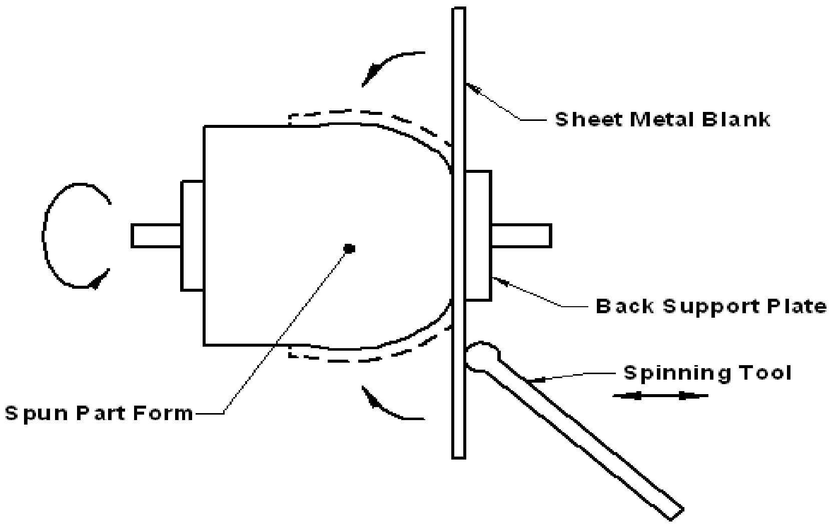


Fig:1 Metal Spinning

1.1 Metal Spinning

Metal spinning is a forming process in which a disc of metal is revolved at controlled speeds on a specialized machine similar to a lathe. At the head end of the machine, instead of a chuck to clamp the work piece, a spinning mandrel made of hard maple or metal is mounted to the machine. The mandrel's form corresponds to the internal contour of the part to be produced. The round blank is clamped between the spinning mandrel and tailstock spindle; then the blank and mandrel are rotated together. During rotation, a roller or other spinning tool makes multiple passes over the blank, forcing it against the mandrel and causing the metal to flow mechanically, taking the shape of the internal form. The roller or spinning tool may be forced through its motion by hand or auxiliary power, such as a hydraulic cylinder. The size of the part and the thickness and alloy of the blank will determine the force required to cause the metal to "flow" effectively over the mandrel. Metal spinning is a forming process which produces hollow parts that are typically circular in cross-section. The basic spinning process starts with a flat metal disc (blank) which rotates on a lathe. This rotating blank is pressed against a tool (mandrel, chuck) which duplicates the interior of the part. This pushing action over the tool results in a formed part. The basic metal spun shapes are the hemisphere, cone, cylindrical shell, and venture as well as others, depicted in Figure 2 below.

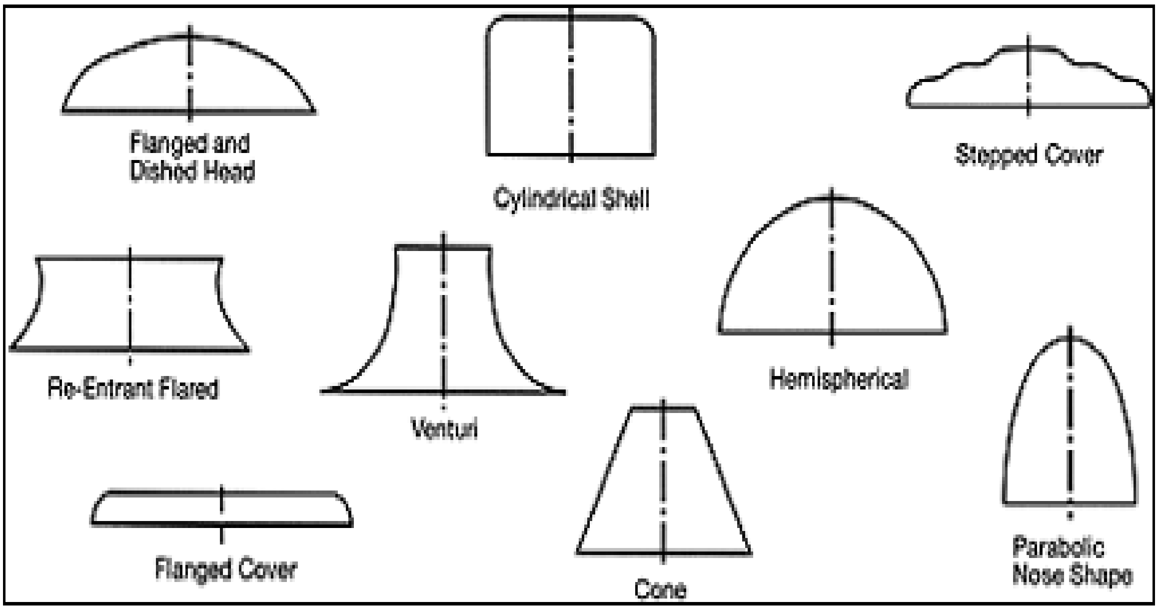


Figure 2. Typical shapes produced by the metal spinning process. Products produced by spinning are utilized in many industries: aerospace, agricultural, computer, ventilation, lighting, marine, food service, automotive, etc.

Metal spinning used to be associated with prototypes and low volume production only. However, with the introduction of automatic lathes, spinning is now a cost effective option for high volume production. The relatively inexpensive tooling price for spinning still makes this forming method a cost effective one for fabricating prototypes.

Spinning is generally used to reduce the overall cost of producing a limited number of parts. At Century, spinning is an economical and efficient process to use, when tooling & engineering costs of other methods are not justified for the quantity, shape or size of the part.

1.2 Metal Spinning Tooling Composition

Tooling for spinning can be fabricated from various materials. Many factors determine which material is most appropriate: production volume, finish, tolerancing, metal, etc. The three basic alternatives are wood, plastic and steel.

Wood tools are made from a variety of materials: maple, fine grain particle board, etc. Wood tools are typically used for parts where tolerancing and/or finish are not critical.

Plastic. A paper-based plastic is also used for tooling. As compared to wood, plastic tooling is generally more durable, provides a superior surface finish and will maintain closer tolerances.

Steel tools are mainly used to form shapes fabricated from stainless steel or other strong metals. Due to the relatively hard, smooth surface of steel tools, parts spun on steel tooling can achieve a superior surface finish and maintain close tolerancing. Steel tools can be fabricated from both mild steel and tool steel. The life of the tool can be increased through heat treating.

Tooling Design

Spinning tooling can be grouped into three broad categories: male, female, and collapsible

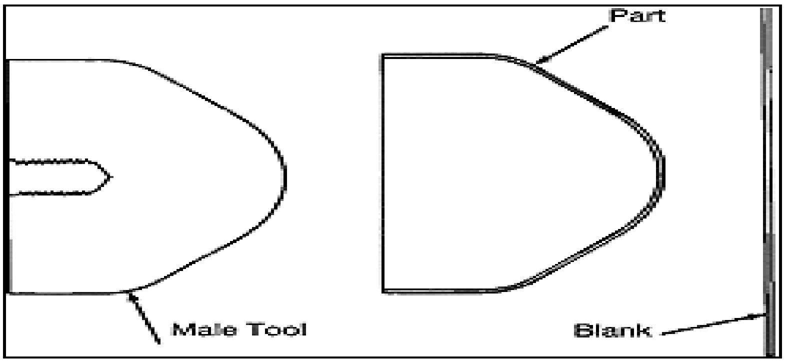


Figure: 3. Relationship of male tool, finished part and starting blank

Male Tool. A male tool is the most common type of spinning tool. It duplicates the interior dimensions of the part. See Figure 3.

Female Tool. A female tool conforms to the exterior dimensions of the part. This type of tool is often used to form flanges and returns.

Collapsible Tool (Segmented). A collapsible tool is required when the diameter of the part becomes smaller as the part is formed. If a male tool is used this smaller diameter or neck prevents the part from being removed from the tool; therefore, a collapsible tool is required. A collapsible tool has a removable center core which keeps the perimeter pieces in place during spinning. After the part is spun, the core is removed which permits access to the perimeter pieces. Note that the use of a collapsible tool involves assembling and disassembling the tool for each piece spun.

1.3 Types of Spinning 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 .

The primary tools are the Sheep's nose used for most of the forming, and the Duck's bill use for finishing (see Fig:4 below) 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 cross feed 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.

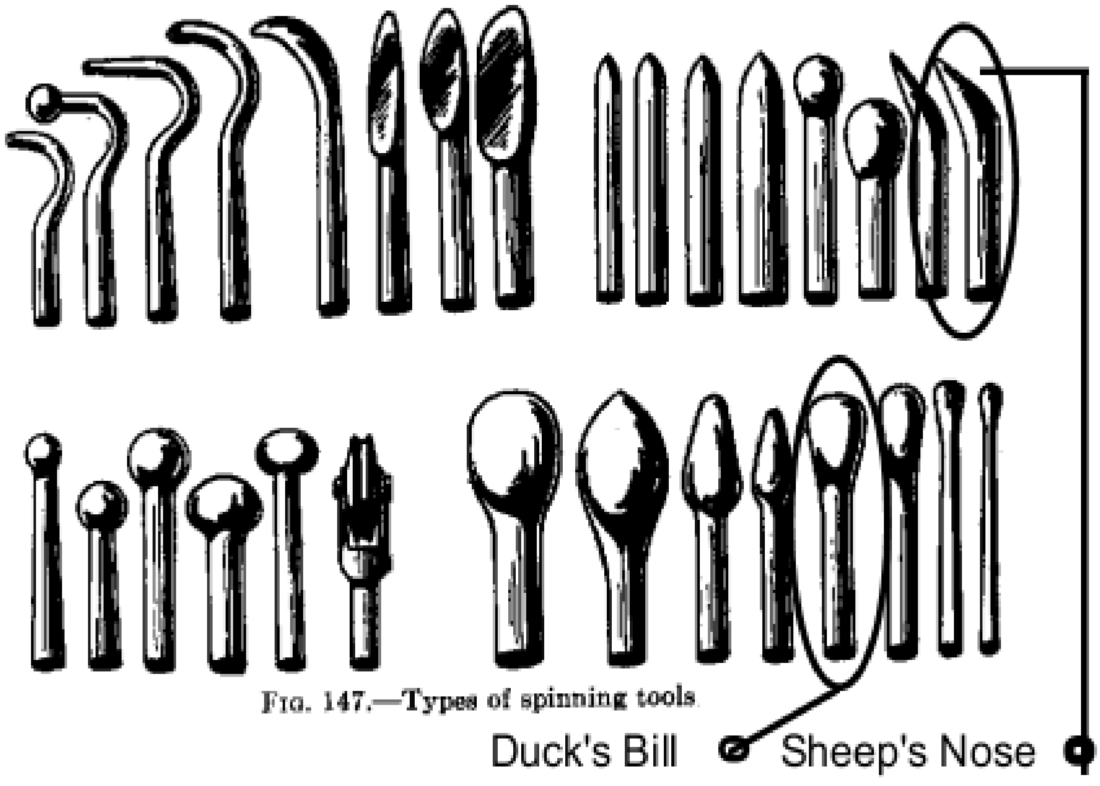


Fig: 4. Types of spinning tools

Custom grooving or forming tools can be easily fabricated and even mounted directly to the cross feed if it is a simple form. Spinning with the tool attached to the cross feed 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.

1.4 Basic Operations of Metal Spinning

In forming a part by spinning, a combination of processes may be utilized to complete a part. These processes include: preforms, conventional spinning shear spinning, edge treatment (trimming, beading, curling, and hemming) as well as secondary operations.

Preforms. A preform is a partially formed part which is used to increase the efficiency of the next forming process. Preforms may be in the shape of cylindrical shells, cones, and more. These preforms can be achieved through spinning or other forming operations such as drawing.

Conventional Spinning. The spinning process usually involves a series of passes to complete the formed part. During each pass the metal is stretched thus thinning out the material. This thin-out characteristic is typical of the conventional spinning process. If necessary thin-out can be minimized.

Shear Spinning. is a variation of conventional spinning. Shear spinning refers to the formation of a part in just one pass. This process allows for an accurate prediction of finished material thickness. Shear spinning is typically associated with conical and cylindrical shapes.

In-house or will subcontract them for you. Edge Treatment. The edges of a spun part can be finished in many ways. Parts can be trimmed for a straight edge, hemmed for a folded edge, or beaded for a rolled or curled edge. These edge treatments can be performed in a spinning lathe or on a separate machine.

Secondary Operations. Often spun parts require secondary operations. This may range from piercing holes, to heat treating, to powder coating, to laser cutting. Many metal spinning companies perform these operations.

1.5 Types of Spinning Process

Manual Spinning lathes typically accommodate blanks ranging from 0.25 in.(6.35mm) to 72 in. (1.8 m) in diameter. Larger manual lathes are available to accommodate blanks of up to 160 in. (4.1 m) in diameter.

Power Assisted Spinning is manual spinning augmented by hydraulic cylinders which provide additional force on the work piece rather than only human force. This additional power is useful when forming strong metals such as stainless steel and exotic alloys.

Automatic Spinning is based on Computer Numerical Control (CNC) and Programmable Numerical Control (PNC). For PNC, the lathe is programmed through a "teach" mode where the first work piece is manually spun while the computer records the movements. Once this initial work piece has been spun, the lathe is put into "playback" mode for production. Blanks are positioned in the lathe by the operator and the playback cycle is initiated. The work piece is then formed automatically, exactly duplicating the movements of the manual spinning. Automatic spinning is a cost effective option for medium and high volume production since it offers high repeatability and fast cycle times.

1.6 Metal Spinning Process

The diagram (Fig: 5 below) shows a basic setup for a horizontal spinning lathe. The tool (mandrel, chuck) is mounted to the headstock of the lathe. A follower block (tail block) is mounted to the tailstock.

A circular blank is then clamped to the tool by advancing the follower. The tool rest and pin provide a support system for the lever arms, applies pressure to the blank via a roller or other forming tool. The movement of the roller across the blank is called a pass. A series of passes, which ultimately forms the completed part, is achieved by repositioning the lever arms incrementally.

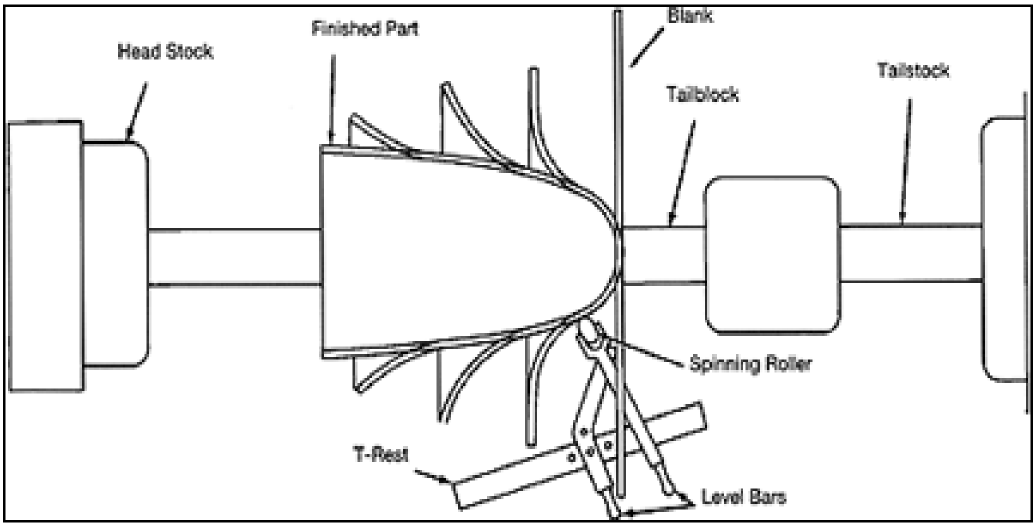


Figure: 5. Manual spinning. The sequential development of the finished part in several passes is shown.

Metal Spinning Equipment Metal spinning lathes can be grouped into three broad categories: manual, power assisted, and automatic. Each paragraph below provides a brief outline of the equipment and typical applications.

Spinning sheet metal on the lathe is an excellent means for quickly prototyping round hollow metal forms. 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

The mechanical working of the metal during the spinning process refines and strengthens its grain structure, as well as eliminating hidden and surface discontinuities to improve metal integrity. The process is particularly adaptable to concentric circular shapes and segments and can present considerable savings in materials and machining when compared to cast or forged parts. Spinning also makes it possible to produce components with thinner wall thicknesses directly, without machining them down to size. Simple tooling requirements, involving primarily a contoured spinning mandrel, reduce lead times and keep tooling costs relatively low, particularly for prototype and limited production quantities.

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 our 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.

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-H32 , 6061-T 6 , etc.). H denotes strain hard enable 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 significantly 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

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 our 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 we 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. Reshape and wood are the cheapest buck-making materials, with Reshape 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.

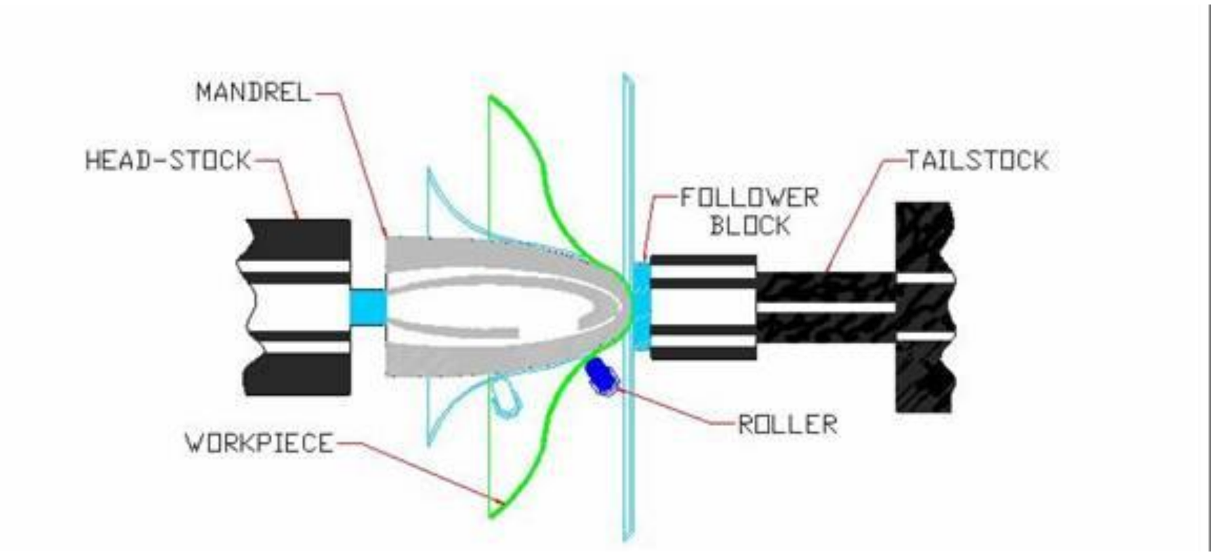


Fig: 6. Mandrel

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 Reshapes 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.

FORMING

Forming is accomplished by working with the material, feeling its structure, its grain, its hardness, its willingness to move in the directions that we want it to. It is critical that one be sensitive to the material's willingness to move so that we 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)].

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 misaligning 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 is laid down onto the mandrel the bump will flare out again.

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. 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 band saw 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.

1.7 Manufacturing Menu / Metal Spinning Manufacturing Services Manufacturing Service Providers

Metal Spinning, also called spun metal manufacturing is a manufacturing process that forms sheet metal into a cylindrical or circular shape. The Blank sheet metal is rotated about an axis while a form tool is pressed against the part into a chuck shape tool to form a desired shape. Metal Spinning typically require low cost tooling when compared with similar processes, such as, drawing and punching manufacturing. Spinning tools are simple and easy to setup. Small production numbers are practical with metal spinning manufacturing. Labor costs tends to be higher, however these cost are easy to justify with low volume manufacturing vs the high tooling costs of other processes.

Materials which may be used in Spinning Manufacturing:

- Aluminum
- Brass
- Copper
- Steel – Cold Rolled
- Steel – Hot Rolled
- Inconel
- Stainless Steel

CHAPTER TWO

Applications, Advantages, Limitations, Affects and Benefits of Metal Spinning

2.1 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 venture 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.

2.2 ADVANTAGES

--Spinning tooling is relatively inexpensive due to its simplicity and composition.

--This simplicity translates into short lead times for new parts Design changes can usually be made at a minimum of expense again due to the inexpensive nature of the tooling.

--The factors above combine to make spinning ideal for prototypes. Spinning is typically a cold working process; therefore, spinning increases the tensile strength of the material.

--The spinning process can accommodate very large parts in excess of 120 in. (3.0 m) in diameter as well as parts requiring thick material such as 0.500 in. (12.7 mm) mild steel.

2.3 LIMITATIONS

Extreme tolerance requirements may dictate the use of secondary operations.

Manual spinning is more labor intensive than automatic spinning or other forming processes such as drawing.

The uniformity of a manually spun part is closely associated with the skill of the operator.

2.4 AFFECTS

The following design guidelines for metal spinning can affect quality and cost.

It is preferable to specify the inside diameter (I.D.) and associated tolerance since the outside diameter will vary due to material thin-out. If necessary, a specific outside diameter (O.D.) can be maintained.

If uniform wall thickness is required, identify the portion of the part which is affected.

Additional operations may be required to achieve this uniform wall thickness.

Corner radii should be specified at 2 to 3 times material thickness.

Tighter radii can be achieved on thicker material and through secondary operations.

If concentricity is critical, specify the total indicated run out (TIR) and indicate if this applies in the restrained or unrestrained condition of the part.

Working closely with our spinning supplier during the design phase may significantly improve formability and reduce cost.

If tight tolerance is required in a small area only, specify that area. The erroneous assumption that the tight tolerance applies to the entire part will dramatically increase the price of the part.

Surface finish is affected by the material, thickness, tool condition, forming speed, and other factors. If the specified surface finish cannot be achieved through spinning, secondary operations can be performed.

Any formable metal can be spun. The stronger the material the more difficult the spinning.

TOLERANCES

The tolerance guidelines for spinning are shown in Table 1.

Table I. Tolerances for metal spun parts which are typically found practical for most applications

Diameter of Finished Part	Commercial Applications	Special Applications
Up to 24" Diameter (600 mm)	+/- 0.015" to 0.031" (0.38 mm to 0.79 mm)	+/- 0.001" to 0.005" (0.02 mm to 0.13 mm)
25" to 36" Diameter (600 mm to 900 mm)	+/- 0.031" to 0.047" (0.79 mm to 1.19 mm)	+/- 0.005" to 0.015" (0.13 mm to 0.38 mm)
37" to 48" Diameter (900 mm to 1200 mm)	+/- 0.047" to 0.062" (1.19 mm to 1.57 mm)	+/- 0.010" to 0.030" (0.25 mm to 0.76 mm)
49" to 72" Diameter (1200 mm to 1800 mm)	+/- 0.062" to 0.094" (1.57 mm to 2.39 mm)	+/- 0.015" to 0.045" (0.38 mm to 1.14 mm)
73" to 96" Diameter (1800 mm to 2400 mm)	+/- 0.094" to 0.125" (2.39 mm to 3.17 mm)	+/- 0.020" to 0.060" (0.15 mm to 1.52 mm)
97" to 120" Diameter (2400 mm to 3000 mm)	+/- 0.125" to 0.156" (3.17 mm to 3.96 mm)	+/- 0.025" to 0.090" (0.64 mm to 2.29 mm)

2.5 Benefits of Metal Spinning

Short Turnaround

Compared to other metal forming processes, metal spinning has a much shorter turnaround on tooling. It is not uncommon to have a finished part utilizing metal spinning within the time-frame it takes just to make the tooling with other processes.

Lower Tooling Cost

Due to the tool design simplicity, tooling cost is generally lower compared to other manufacturing processes.

Flexibility in Tooling

Depending on volume, tolerance, and capability of the part tooling material options include tool steel, engineered plastics, and wood.

Ease of Design Change

Changes in part design can often be made through changes in tooling, particularly if the change is a reduction in size.

Small to Large Volume

Manual or semi-automated equipment can be used to handle prototype or small production runs. Large volume runs requiring tight tolerances are produced on state-of-the-art automated CNC equipment.

Multi-Process Production

Metal spinning can be combined with other processes such as deep drawing, rolling, and welding to manufacture more challenging designs.

Improved Metallurgy

Metal Spinning (vs other technologies) improves the metallurgy by realigning the grain structure of the metal. Tensile strength is improved allowing lighter gauge material to be used in the same application.

2.6 LUBRICATION AND SAFETY OF METAL SPINNING

LUBRICANT

A lubricating wax or grease is essential to a quality finish and just being able to remove our 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 Shop Tools or Dan mar) 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 work shirt 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 our tool every time we 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 war page), 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.

2.7 Manual Spinning of Metallic Components

General Description. Manual metal spinning is practiced by pressing a tool against a circular metal preform that is rotated using a lathe type spinning machine. The tool typically has a work face that is rounded and hardened. Some of the traditional tools are given curious names that describe their shape, such as "sheep's nose" and "duck's bill."

The first manual spinning machine was developed in the 1930s. Manual metal spinning involves no significant thinning of the work metal; it is essentially a shaping technique. Metal spinning can be performed with or without a forming mandrel. The sheet preform is usually deformed over a mandrel of a predetermined shape, but simple shapes can be spun without a mandrel. Various mechanical devices and/or levers are typically used to increase the force that can be applied to the preform. Most ductile metals and alloys can be formed using metal spinning. Manual metal spinning is generally performed without heating the work piece; the preform can also be preheated to increase ductility and/or reduce the flow stress and thereby allow thicker sections to be formed. Manual metal spinning is used to form cups, cones, flanges, rolled rims, and double-curved surfaces of revolution (such as bells). Typical shapes that can be formed by manual metal spinning are shown in Fig. 8; these shapes include components such as light reflectors, tank ends, covers, housings, shields, and components for musical instruments. The maximum practical component diameter is often limited by the size of the available equipment. The upper limit of component thickness increases as perform ductility increases or as flow stress decreases. For example, the manual spinning of aluminum as thick as ~6 mm (0.24 in.) is possible. The practical maximum thickness of low-carbon steel that can be deformed by spinning without mechanical assistance is ~3 mm (0.12 in.). Manual metal spinning has several advantages and several disadvantages over alternate processes such as press forming or forging. There are three advantages of manual metal spinning. First, the tooling costs and investment in capital equipment are relatively small (typically, at least an order of magnitude less than a typical forging press that can effect the same operation). Second, the setup time is shorter than for forging. Third, the design changes in the work piece can be made at relatively low cost.

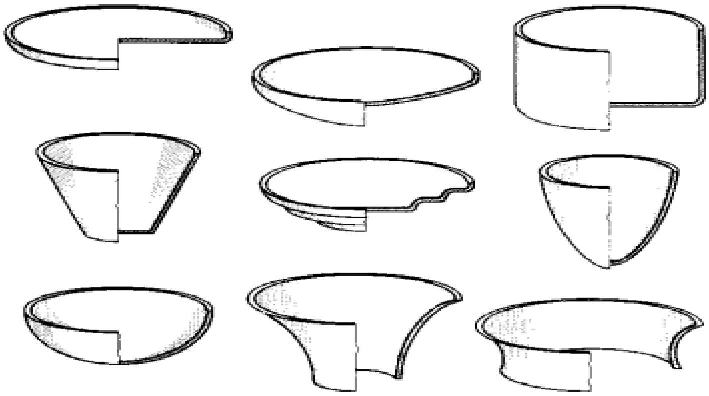


Fig. 7 Typical components that can be produced by manual metal spinning. Conical, cylindrical, and dome shapes are shown. Some product examples include bells, tank ends, funnels, caps, aluminum kitchen utensils, and light reflectors.

Equipment for Manual Spinning—Lathes and Tooling. A simple tool and sheet perform setup for manual metal spinning is shown in Fig. 8(a). The forming mandrel is mounted on the headstock of a lathe. The circular preform is clamped to the mandrel by the follower. Pressure is applied at the tailstock by means of an antifriction center and suitable pressure to form the component. The tool rest and pedestal permit the support pin (fulcrum) to be moved to various positions. Metal spinning is performed by manually applying the friction-type spinning tool as the preform is rotated. Figure 8(b) shows a more complex setup for manual metal spinning. In this arrangement, the spinning rollers are mounted in the fork sections of long levers, and the tool support has a series of holes to adjust the tool position. The roller is manipulated by moving two scissor like handles around the perform / work piece. Horizontal metal-spinning lathes that can spin preforms with diameters in the range of ~6 mm to 1.8 m (0.24 in. to 5.9 ft) have been built.

For large-diameter parts that may be formed at high speeds, special pit lathes (per the safety requirements) that permit the spinning of blanks as large as ~5 m (16 ft) in diameter have been built. Standard lathes can also be fitted with special tooling for making ovular parts. Tooling costs are generally low for manual spinning. However, manual spinning is generally performed using multiple passes, and tool life can be low.

Hydraulic lathes were introduced after about 1945 for forming components with either a thicker section or higher-strength alloys. A reliable spinning machine must possess a significant mass in order to ensure stability; the mass provides vibration-free operation when producing components to tight and repeatable tolerances at high speed. The high speeds associated with metal-spinning processes require considerations for all safety aspects of the process. Mandrel technology plays a very important role in metal spinning.

The mandrels are also sometimes referred to as form blocks or spin blocks for manual spinning. The mandrels can be made of seasoned hard-maple wood or metals or combinations of the two. Most hardwood mandrels are constructed by gluing strips of 25 to 50 mm (1.0 to 2.0 in.) thick maple into the main block to create a cross-laminated structure to increase strength. Such mandrels are stronger and more durable than mandrels machine from a solid block. Some wooden mandrels are reinforced with steel at the ends and at small radii, to ensure maintenance of radii in the final part. Minimum inside radii of 1.6 mm (0.06 in.) are possible using mandrels of appropriate construction; corners with radii of smaller than 1.6 mm (0.06 in.) are not desirable. Corners with radii of greater than 3 mm (0.12 in.) are preferred where possible. Other mandrel materials include steel, cast iron, aluminum, magnesium, and plastic-coated wood.

When it is necessary to produce parts to close tolerance, the mandrels are typically made entirely of steel and cast iron. Cored castings of steel or cast iron are preferred in order to reduce the rotating weight. Mandrels must be statically balanced, and, when used at high speed, the mandrels should also be dynamically balanced. Simple metal-spinning tools can be made by forging carbon or low-alloy tool steels to the desired shape and hardening the working surfaces to a hardness of ~60 HRC.

The rollers also need to be polished when surface finish of the final part is important. Typically, the rollers are made of hardened tool steel or aluminum bronze.

2.8 Process Technology for Manual Spinning.

Manual metal spinning is extensively used for prototypes or for production runs of less than ~1000 pieces, because of the low tooling costs. Larger volumes can usually be produced at lower cost by power spinning or press forming. For large-quantity production, power spinning can generally be conducted at lower cost than manual metal spinning. For example, a stainless steel cover for a food processing machine (with a shape similar to that shown in the middle of Fig. 8) can be produced economically at the rate of 100 per year using manual metal spinning. Conical parts are ideally suited for metal spinning because only one tool is required; drawing in dies would require four or five operations. Many such cones can be spun in one operation at a moderate production rate, depending on their included angle. For large-quantity production, power spinning is generally less expensive than manual metal spinning. In cone spinning, the deformation of the metal from the flat blank is performed in accordance with the sine law, as is described in more detail in the section "Mechanics of Cone Spinning" in this article. The rotational speeds that are best suited to manual metal spinning depend mainly on work metal composition and thickness. For example, a given blank of stainless steel can be spun at a surface speed of 60 m/min (200 surface feet per minute, or sfm). Under otherwise identical conditions, changing to an aluminum blank will permit speeds of 120 to 180 m/min (400 to 600 sfm).

Selection of optimal speed depends largely on operator skill. In many metal-spinning operations, speed is changed (usually increased) during the operation by means of a variable speed drive on the headstock. The dimensional tolerances that can be achieved by manual spinning increase as the diameter of the component decreases. For components up to 300 mm (12 in.) in diameter, tolerances of +0.20 mm (0.008 in.) can be achieved. For larger-diameter components, the tolerances are worse. For example, parts ~ 4 m (13 ft) in diameter can only be produced to tolerances of approximately +1.0 mm (0.04 in.), but this is machine dependent.

Lubricants generally need to be used in all metal-spinning operations, regardless of the preform composition or shape or the type of metal-spinning tools that are used. Lubricants are typically required both before and during forming. The need for lubrication during spinning depends on the tenacity of the lubricant used and on the rotational speed of the preform. The lubricant must continue to adhere to the rotating perform during spinning. Ordinary cup grease is often used. It can be heated to reduce its viscosity, for ease of application. Other lubricants used for metal spinning include soaps, waxes and to allows, and pigmented drawing compounds; in the selection of the most suitable lubricant, the ease of removal of the lubricant after forming has to be considered.

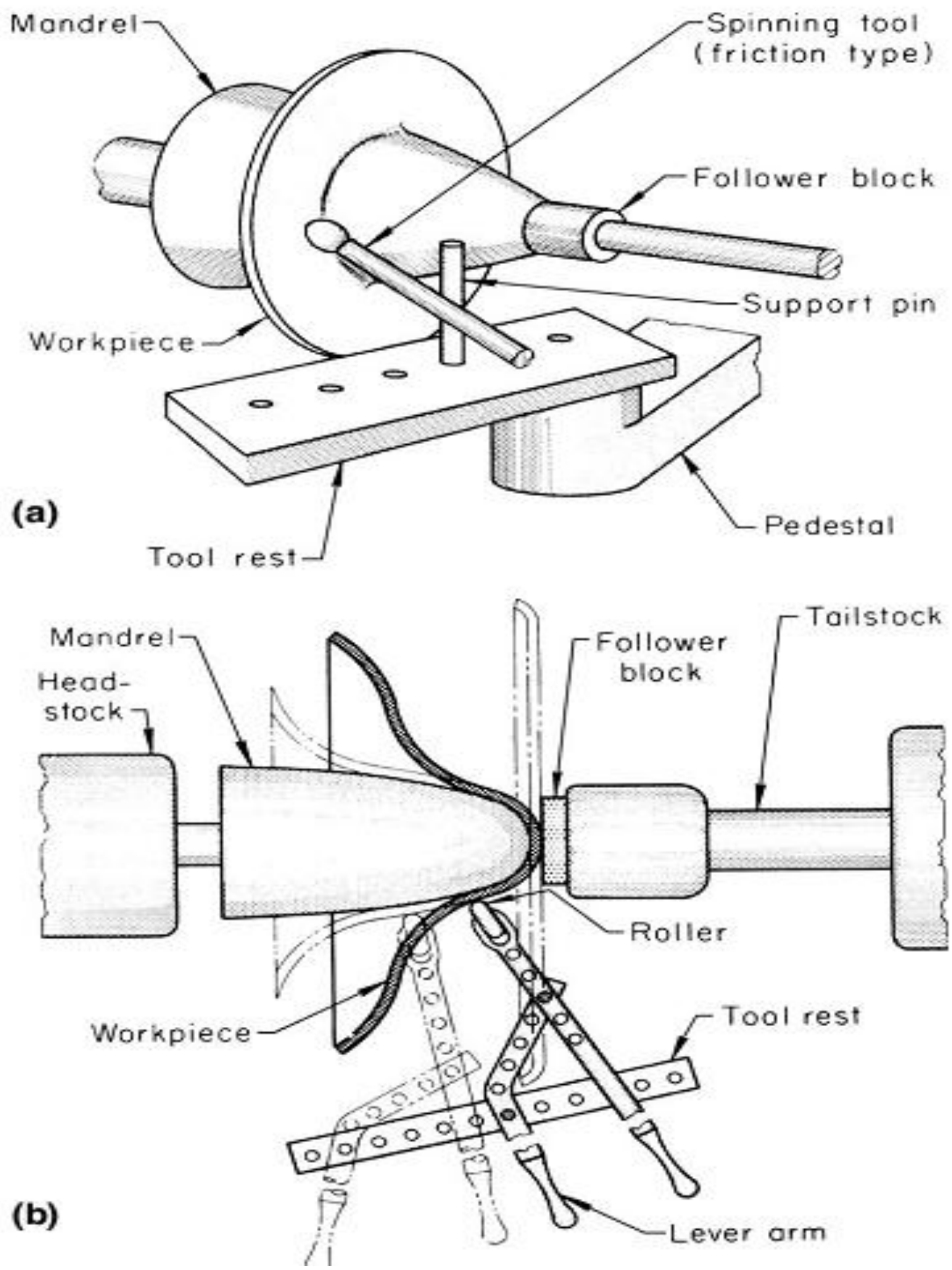


Fig: 8 Typical arrangements for manual spinning using a lathe. (a) Simple arrangement with a friction type spinning tool. (b) More complex setup using levers and a spinning roller

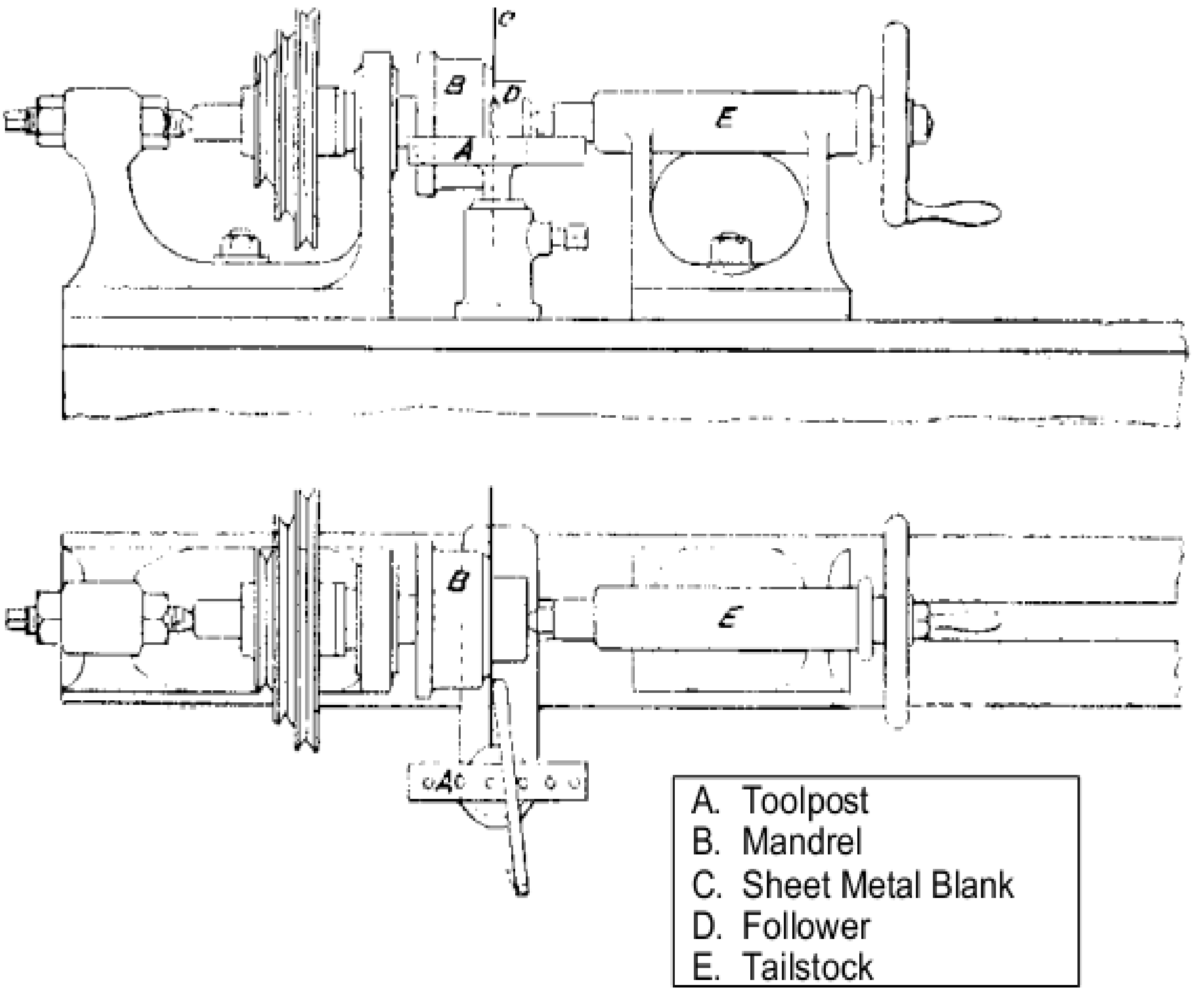


Fig: 9 Lathe Machine

2.9 Disadvantages of manual metal spinning.

First, Highly skilled operators are required, because the uniformity of the formed part depends to a large degree on the skill of the operator.

Second, Manual metal spinning is usually significantly slower than press forming.

Third, The deformation loads available are much lower in manual metal spinning than in press forming. Manual metal spinning and power spinning are generally in competition with pressing and deep drawing.

2.10 Power Spinning

General Description. Power spinning of metals and alloys is also known as shear spinning, because in this method metal is deformed using high shear forces (up to 3.5 MN, or 800,000 lbf). There are two broad applications of power spinning: metal cone spinning and metal tube spinning. In cone spinning, the deformation of the metal from the flat blank is performed in accordance with the sine law, as is described subsequently. Almost all ductile metals can be shaped using power spinning (provided they have a minimum ductility of ~2%). Products range from small hardware items made in large quantities (metal tumblers, for example) to large components for aerospace applications in low-volume production. A classic low-production volume example of power spinning involved the Concorde engine compressor shaft, which was formed by a combination of forging and spinning, because this was more efficient than forging alone. Metal blanks as large as 6 m (20 ft) in diameter have been successfully formed using power spinning. Conical and curvilinear shapes are most commonly produced from flat (preformed) blanks by power spinning. Plate stock up to 25 mm (1.0 in.) thick can be power spun at room temperature. Blanks as thick as 140 mm (5.5 in.) have been successfully spun at elevated temperature.

Mechanics of Cone Spinning. The most common application of power spinning is for conical shapes. In this variant, the metal is volumetrically displaced in the axial direction. The metal deformation occurs in accordance with the sine law, which relates the wall thickness of the starting blank, t_1, and the wall thickness of the finished work piece, t_2, as $t_2 = t_1 (\sin\alpha)$, where α is half the apex angle of the cone (assuming uniform wall thickness in the conical section). The diameter of the finished component is the same as that of the starting blank. When metal spinning is performed in accordance with the so-called sine law, the thickness of the component in the axial direction is the same as the thickness of the starting blank (Fig. 10). The arrangement shown in Fig. 10 is for cone spinning using a single pass. When spinning metal cones to small singles ($<35^0$ included angle), it is generally easier to use multiple spinning passes with different cone angles for each pass, as illustrated in Fig. 11; typically, the component is annealed or stress relieved between passes. The practice of multiple passes with intermediate anneals permits a high total reduction while maintaining a practical reduction limit of 50 to 75% between process anneals. The reduction between successive annealing operations is determined by the maximum deformation limit for the metal being spun, as is described subsequently.

Deformation limits are shown for a range of alloys in Table 2; the deformation limit is obtained by multiplying the thickness of the starting preform, t_1, by the maximum reduction factor and then dividing the result by t_1 to obtain the sine of the half-angle required for the conical mandrel. In power spinning of small angle cones (as shown in Fig. 11), even when multiple pass spinning is used, the original blank diameter is retained, and the exact volume of material is used in the final part. At any diameter of either the preform or the completed work piece, the axial thickness equals the thickness of the original blank. For example, if a flat plate has a diameter of 190 mm (7.5 in.) and a thickness of 12.5 mm (0.5 in.), the spun preform has the same 12.5 mm (0.5 in.) axial thickness, but the wall thickness is only 6.25 mm (0.25 in.) (t_2 in Fig. 11), thus satisfying the sine law. Similarly, the final work piece has an axial thickness of 12.5 mm (0.5 in.), but in accordance with the sine law, it has a wall thickness of only 3.1 mm (0.125 in.) (t_3 in Fig. 11). Deviations from the sine law that can occur are usually expressed in terms of over reduction or under reduction. In over reduction, the final thickness of the work piece is less than that indicated by the sine law; in under reduction, the thickness is greater. In over reduction, the flange on the cone will lean forward; in under reduction, the flange on the cone will lean backward. If a thin blank is spun with severe under reduction, the flange can also wrinkle.

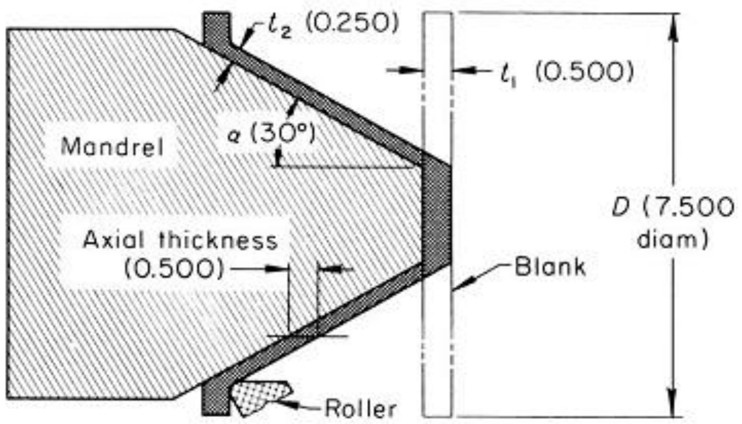


Fig. 10 Typical arrangement for power spinning a cone in a single operation. The mandrel diameter is 188 mm (7.5 in.), t_1 is the thickness of the preform, and t_2 is the wall thickness of the final conical component . The included angle of the cone is α. For the case of power spinning, the diameter of the final component is the same as the starting sheet preform. Dimensions given in inches.

Table 2 Maximum perform thickness reductions (approximate), or deformation limits for single-pass power spinning of a range of metals and alloys

Typically, the maximum reduction that can be employed to form a hemisphere is less than can be used for forming a cone.

Material	Maximum reduction for a cone, %	Maximum reduction for a hemisphere, %
Aluminum alloys		
2014	50	40
2024	50	...
3000	60	50
5086	65	50
5256	50	35
6061	75	50
7075	65	50
Beryllium	35	...
Copper	75	...
Nickel alloys		
Waspaloy	40	35
René 41	40	35
Steels		
4130	75	50
4340	70	50
6434	70	50
D6ac	70	50
H11	50	35
Stainless steels		
321	75	50
347	75	50
410	60	50
17-7PH	65	45
A-286	70	55
Titanium		
Commercially pure titanium	45	...
Ti-6Al-4V	55	...
Ti-3Al-13V-11Cr	30	...
Ti-6Al-6V-2.5Sn	50	...
Tungsten	45	...

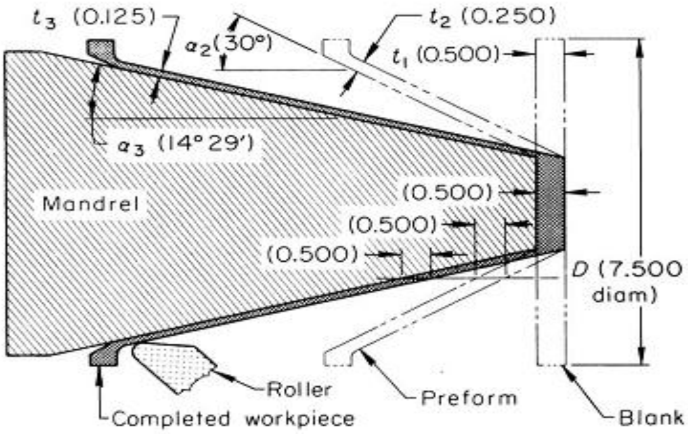


Fig. 11 Typical arrangement for power spinning a cone in two stages. The two-step approach is used for small include d cone angles (35^0 in this figure). Dimensions given in inches

Machines for Power Spinning—Lathes and Tooling. Power spinning is generally performed using special-purpose machines. The significant components of a power-spinning machine are shown schematically in Fig. 12. Although Fig. 12 illustrates power

spinning of a conical shape,

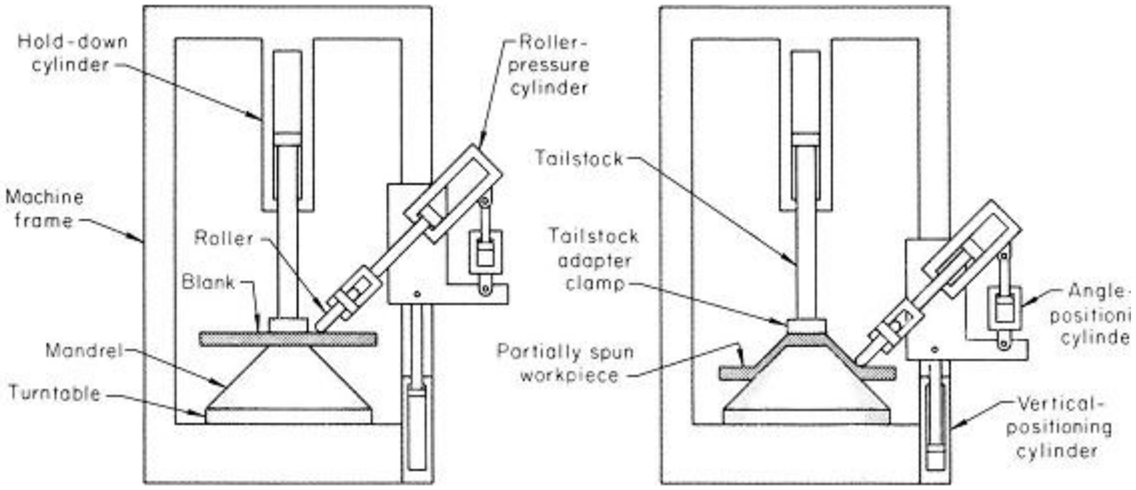


Fig. 12 Schematic diagrams of a vertical arrangement employed for power spinning of large-diameter cones. The diagram shows the preform, clamping cylinder, and the positioning cylinders that are used to control the axial, radial, and angular positions of the roller and for the forming scheme used to generate the cone .

Machines for power spinning are generally specified by the diameter and length of the largest component that can be spun and the maximum load that can be applied to the work. Metal spinning machines can be vertical or horizontal. Machines used for spinning large diameter and large-mass preforms, such as 1.8 m (6 ft) or more in diameter, are usually vertical because they are better suited to handling large components. A broad range of power-spinning machines has been built. The capacity of spinning machines ranges from 455 mm (18 in.) diameter and 380 mm (15 in.) length (maximum component dimensions) to machines capable of spinning work pieces as large as 6 m (20 ft) in diameter and 6 m (20 ft) long. The load on the work can be as great as 3.5 MN (800,000 lbf).During power spinning, the tooling is subjected to more severe service conditions than during manual spinning, and as a result, design and manufacture of the tooling must be performed in a more rigorous manner. The tooling that is used for both the rollers and the mandrels is described in the following paragraphs. A typical mandrel profile for cone spinning is shown in Fig. 13. The flange diameter, dimension A, and the diameter of the nose of the cone, dimension ß, and angle α can be adjusted as required. The usual practice is to have an integral flange to permit the mandrel to be bolted to the headstock. The radius R can vary from a minimum of 0.8 mm (0.03 in.) to a round nose. Mandrel wear or failure can be a problem in the power spinning of cones.

The mandrels used for production spinning of cones must be hard in order to resist wear, and they must have a high fatigue strength in order to resist the fatigue loading due to the normal eccentric loading during power spinning. Failure is typically caused by spoliation of regions from the surface. The materials used for the mandrels for cone spinning are selected primarily on the basis of the desired mandrel life. The most commonly used materials are cast irons and tool steels; the actual mandrel material selection depends on the part design, part material, and desired life.

For example, gray cast iron can be used for the low volume (10 to 100 pieces) spinning of soft metals, and alloy cast iron for spinning 100 to 250 pieces; the mandrels can be hardened in areas of high wear. For high production volumes (250 to 750 pieces), 4150 or 52100 steel hardened to approximately 60 HRC can be used. Tool steels such as O6, A2, D2, or D4 hardened to 60 HRC or slightly higher are more suitable for high-volume production. The surface finish of the mandrels should be at least 1.5 mm (0.06 mil). The mandrel dimensions should be machined so that they are within +0.025 mm (0.0010 in.) of being concentric with each other.

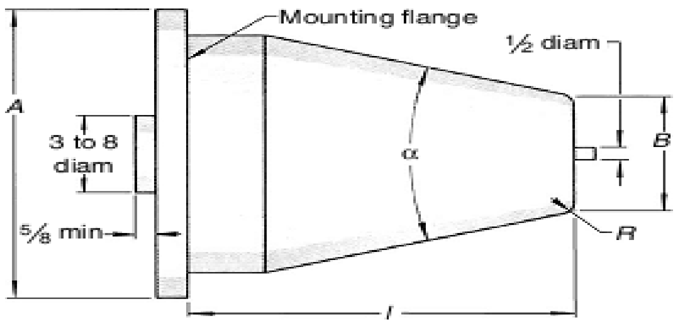


Fig. 13 Typical mandrel used for power spinning of cones. Generally, there are small bosses on the nose and tail for clamping in the tailstock and headstock , respectively. Dimensions given in inches.

Three types of rollers are used in power spinning; these are shown in Fig. 14.

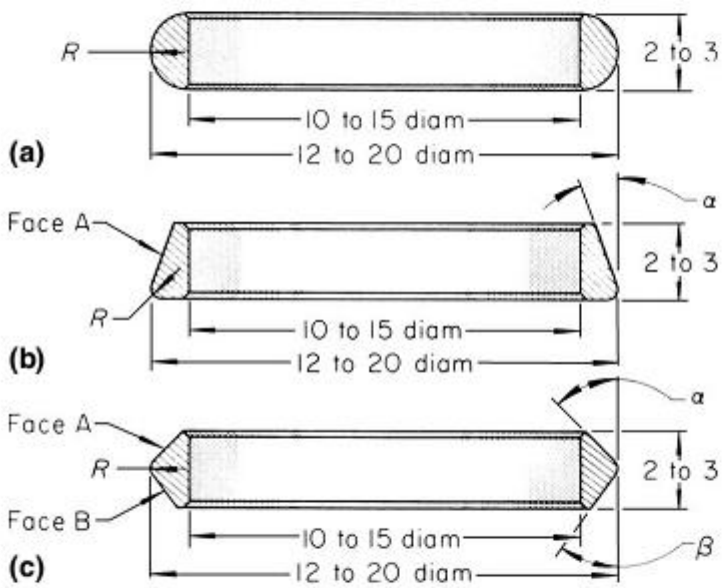


Fig. 14 Diagrams of typical forming rollers used for spinning of cones and hemispheres. (a) Full radius roller. (b) Roller profiled for forming corners. (c) Roller used for reducing the wall thickness. Dimensions given in inches.

The roller designs shown in Fig. 14 typically have outside diameters in the range 305 to 510 mm (12 to 20 in.), depending on the type and size of the spinning machine and the part to be formed. Roller widths are usually 50 to 75 mm (2 to 3 in.). The design of the roller employed depends principally on the shape of the component that is to be formed. The full-radius roller design shown in Fig. 14(a) (two axes of symmetry) is generally used to produce curvilinear shapes, and the designs with the radii of curvature shown in Fig. 13(b) and (c) are preferred for the spinning of cones. The design of the rollers, and the alloy used for the rollers, play a critical role in ensuring efficient power spinning. The roller angle a shown in Fig. 14(b) and (c) is adjusted to suit the geometry of the component that is being spun (the included angle of the cone has a significant effect on selection of roller design). This roller angle is selected to provide clearance such that the work metal does not contact the faces of the roller where the metal is being deformed (surfaces A and B, shown in Fig. 14(c). The radius R should not be less than the final wall thickness. the final wall thickness. The roller design illustrated in Fig. 14(b) has been widely used for cone spinning. A typical arrangement for cone spinning, using two opposed rollers, is shown in Fig. 15. When two rollers are used to spin a part from flat plate, the rollers are positioned at equivalent/ symmetric conditions with respect to the preform. However, when metal spinning is performed from a preform, a lead roller is often used, and it is set ahead of the other by 1.5 to 3 mm (0.06 to 0.12 in.). The angle between the axis of rotation of the rollers and the surface of rotation of the work piece (angle ß in Fig. 15) is typically $\sim 10^0$. The angle between the axis of rotation of the roller and the peripheral face of the roller (angle γ in Fig. 15) can be adjusted for different shapes, and it is also often adjusted during the forming operation; this angle is shown in Fig. 15 as approximately 30^0 . Rollers for power spinning are typically made from tool steel or tungsten carbide. A variety of tool steels have been employed, including W2, O6, D2, and D4. The roller material is selected on the basis of the number of parts that are to be formed.

D2 and D4 tool steels are preferred for high-production quantities (they should be hardened to 60 to 65 HRC). Tungsten carbide is only used for specialized applications when the high cost can be justified. The rollers should be polished to a maximum surface roughness of 0.25 m m (0.010 mil).

Process Technology for Power Spinning. An important factor in power spinning is the deformation limit, or so-called spin ability, of the metal; the spin ability is the smallest section thickness (or the maximum reduction in thickness) to which a component can be formed by metal spinning without failure of the component. A simple test has been established to determine deformation limit (or spin ability) of a metal, as shown in Fig. 15. The deformation limit, or spin ability, test is performed by spinning a circular blank over an ellipsoidal mandrel, and spinning is performed so that the outside diameter of the final component is the same as the initial blank.

Because the thickness is eventually reduced to zero for the ellipsoidal mandrel, all metals will eventually fail at some thickness, t_f. The deformation-limit data on a range of materials with different tensile strengths and different form abilities are shown in Fig. 17 and Table 1.

The deformation limit is defined as:

Maximum thickness reduction $=(t_0 - t_f) \times 100/t_0$

The maximum reduction is plotted against the tensile reduction in area of the material in Fig.17. It can be seen that if the metal possesses a tensile reduction in area of 50% or greater, the metal can be reduced by power spinning to a thickness of up to 80% in one pass for spinning a cone.

The maximum reduction that can be employed to form a hemisphere is less than can be employed for forming a cone. Also, any increase in the material tensile ductility (as described by the reduction in area) above 50% reduction in area does not increase formability or spin ability. For materials with low ductility, if the ductility can be increased by increasing temperature, then the formability can be improved. Process parameters, such as the feed rate and the rotational speed, have a less significant effect on the spin ability. The best quality for most components is achieved when spinning at high speeds. The minimum surface speed considered to be practical for metal spinning is approximately 120 m/min (400 sfm), and this is only used for spinning small-diameter work pieces. Surface speeds of 300 to 600 m/min (1000 to 2000 sfm) are typically used; this speed range is suitable for a range of metal compositions, preform shapes, and process conditions (such as reduction per pass, roller design, roller position, and forming temperature).

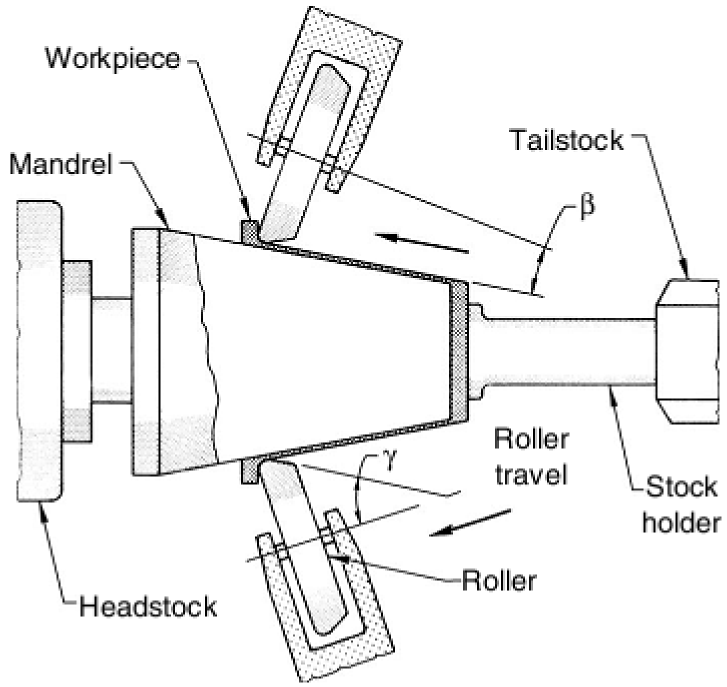


Fig. 15 Schematic diagram showing the relative positions of the preform and two forming rollers used for spinning a cone. One roller can be positioned to follow the second roller, if appropriate for the forming scheme that is being employed.

Most cone-spinning operations are performed at linear feed rates of 0.25 to 2 mm/rev (0.010 to 0.08 in./rev); for typical spinning machines, this equates to linear feed rates in the range 38 to 380 mm/min (1.5 to 15 in./min) (feed rates are usually measured in millimeters per minute). Most machines used in cone spinning are equipped with devices that continuously change the rate of feed with the diameter on which the rollers are working. The feed rate controls the work piece finish and the material properties and the fit of the work piece to the mandrel. With all other factors constant, a decrease in the feed rate will improve surface finish. An increase in feed rate will make the work piece fit tighter on the mandrel, and the finish of the work piece will become coarser. The use of preforms can influence surface finish and is common in cone spinning when the included angle of the cone is less than 35^0 or when the percentage of wall reduction is high.

Preforms are usually prepared by cold forming in a die, although hot forging or machining or a combination of both can be used. The surface finish of a spun component is usually of sufficient quality that no additional machining is required after spinning. The surface finish of spun components can typically be approximately 1.5 mm (0.06 mil), although surface finishes as smooth as 0.5 mm (0.02 mil) have been produced by power spinning, when using appropriate tooling and surface finish of the tooling. A lubricant is almost always used during power spinning. The fluid used serves as both a lubricant and a coolant. A water-based coolant, such as an emulsion of soluble oil in water, is most commonly used, and in large quantities because of the large amount of heat generated.

When spinning aluminum, stainless steel, or titanium, the work pieces or mandrels or both are sometimes coated with the lubricant before spinning. An increase in the forming temperature can lead to a reduction in the flow stress and an increase in the ductility of the preform; this is sometimes required if the load capacity of the spinning machine is not sufficient for cold forming the preform or if the room-temperature ductility of the work metal is too low. When operating at elevated temperatures, great diligence must be exercised in the selection and use of an appropriate lubricant. Power Spinning of Hemispheres. Spinning of hemispheres is more complicated than spinning of cones. However, in order to spin hemispheres, preforms of specially designed geometries can be used to adjust the percentage of reduction as a function of radial position, as is

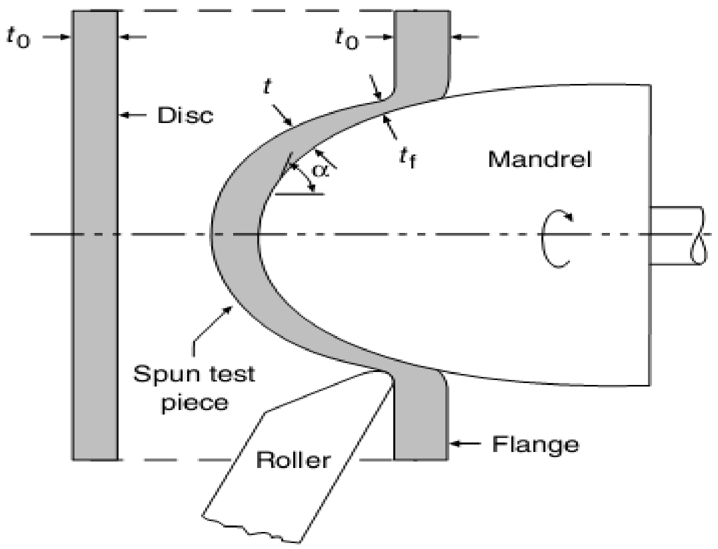


Fig. 16 Schematic diagram of the spin ability test. The thickness of the test coupon is reduced as the roller is advanced; the reduction in thickness at the point of fracture is taken as the maximum spinning reduction per pass. Source: Ref 6

described in the following section. This approach has enabled power spinning to be applied to the forming of hemispheres, ellipses, olive’s, and almost any curvilinear surface of revolution.

However, the design of the preform for curvilinear shapes is more complicated than that for conical shapes. For the case of spinning of conical shapes, it is possible to determine an axial thickness of the spun part that corresponds to the thickness of the blank (Fig. 10, 11). However, the same relationship does not exist for a curvilinear surface; this problem is illustrated in Fig. 18.

In the path from the pole to the equator of a hemisphere, the axial thickness of the metal on a hemisphere changes from stock thickness at the pole to infinity (the inverse of sin 0^0) at the equator (the wall thickness, in the normal direction, goes to zero). The blank thickness must therefore be back-tapered to compensate for the change in thickness that takes place during spinning of hemispheres. Figure 18 shows a perform for a ~ 1.5 m (5 ft) diameter hemisphere; the machined taper started at 3.8 mm (0.15 in.) in thickness in the center of the perform and ended at a thickness of 7.5 mm (0.30 in.) in thickness at the circle where the 30^0 radial line of the sphere was projected to the blank. At the corresponding 45^0 line, the blank thickness was 5.4 mm (0.21 in.), and the final part thickness

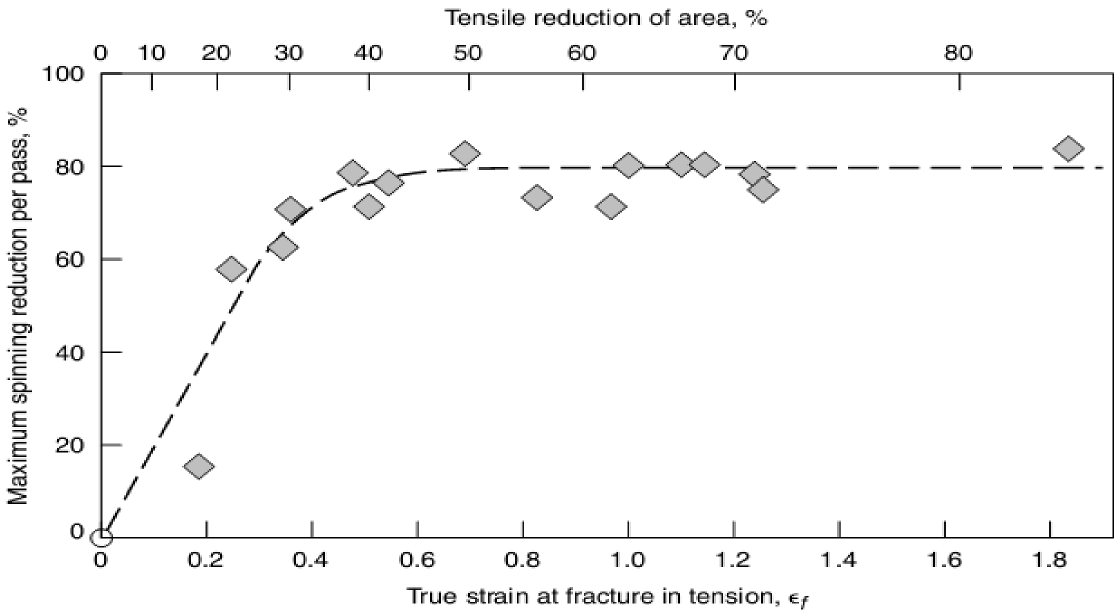


Fig. 17 Maximum spinning reduction per pass as a function of tensile fracture strain for materials of arrange of tensile strengths. For materials with tensile ductility's of greater than 50 %, there is no further increase in the spin ability. Source: Ref 1, 4

was 0.71 times the original thickness. For the region of the hemisphere below the 30^0 line, the reduction of the preform was greater than permissible for spinning aluminum alloy 6061 (according to the previous description), and the forming operation was performed as if spinning a cylinder; the preform for this region had a flange with a thickness proportional to the designed percentage of reduction. As an example, a suitable perform for spinning a hemisphere was designed by first finding in Table 1 the maximum allowable reduction for the material that was used in order to obtain the minimum part thickness associated with the deformation limit and minimum angle of the cone. A beginning stock thickness was selected that, with the maximum allowable reduction, gave the thickness desired in the final hemisphere sphere.

The ratio of finished stock thickness to original stock thickness was then taken as the sine of an angle, which was the angle of the surface at the latitude at which forming was started. Beyond this point, the reduction required to make the hemisphere was greater than is permissible for the 6061 aluminum alloy. At 45^0 from the pole, final part thickness was 0.71 times the original thickness. Forming started at the circle corresponding to the latitude associated with the forming limit (the point where the maximum permissible reduction has taken place). In a cross-sectional view, the circles resulting from the aforementioned approach become points, and the thickness of the stock at these points can be determined. The correct roller locus can be programmed with state-of-the-art CNC-based techniques.

The following example describes forming a 1.5 m (5 ft) diameter hemisphere by power spinning. Large hemispheres (Fig. 18) have been power spun from a solution-treated aluminum alloy 6061 using the following calculations. From Table 1 it was determined that a 50% reduction could be used with this alloy. Preliminary calculations for the thickness of the starting perform indicated a thickness of 7.6 mm (0.30 in.) was required (perform thickness = final wall thickness/maximum reduction = 3.8 mm/2).

In calculating the blank thickness profile for various points on the sphere, it was found that at the pole, or 90^0 point, the thickness had to be reduced to 3.8 mm (0.15 in.) and that a linear reduction was required out to a point directly above the 30^0 tangency on the hemisphere, where the thickness of the starting blank had to be 7.6 mm (0.30 in.).

Beyond this point, a flange was incorporated; the perform thickness was increased in the region by 30% to allow for this flange, and the initial blank thickness was established at 9.9 mm (0.39 in.). Final spinning was accomplished in one pass of the rollers. The type of procedure described in the previous example has also been successfully used to form both hemispheres and ellipses with diameters in the range of 150 mm to 1.8 m (6 in. to 6 ft).

Hemispheres from the following alloys have also been formed: 17-7PH and type 410 stainless steels, alloy steels such as 4130 and 4140, and from aluminum alloys 5086, 2014, 2024, and 6061.

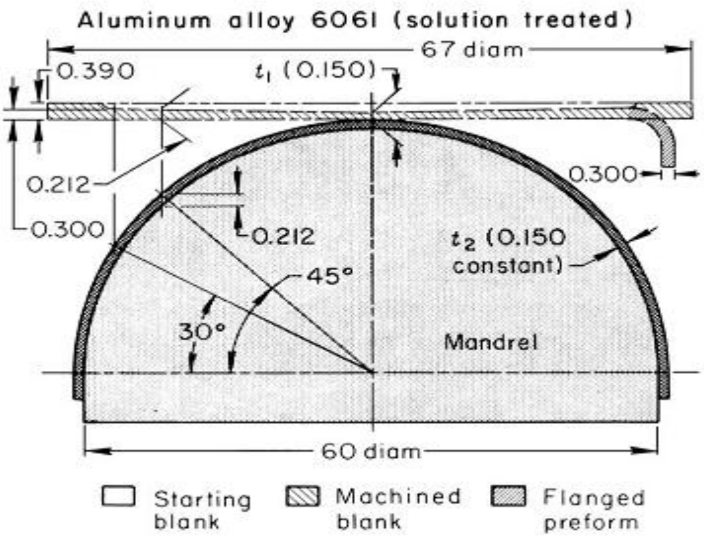


Fig. 18 Schematic diagram showing an example of a forming scheme used to spin a large-diameter hemisphere from a preformed blank metal sheet, such as aluminum alloy 6061. The perform is tapered to allow spinning of a hemisphere with a uniform wall thickness. Dimensions given in inches.

2.11 Effects of Power Spinning on Component Properties.

Power spinning is a severe cold working operation, and it therefore can have a very significant effect on the mechanical properties of the component. Typically, well-defined flow patterns are generated in the grain structure by power spinning. In many applications, the increase in strength caused by spinning is highly desirable, because it eliminates the need for subsequent heat treating. In those applications where the change in mechanical properties is not desired, the component must be annealed after metal spinning.

The effect of power spinning on mechanical properties, such as fatigue performance and creep resistance, is similar to that of other cold working operations.

CHAPTER THREE

SET UP DEVELOPMENT AND EXPEREMENTATION

3.1 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).

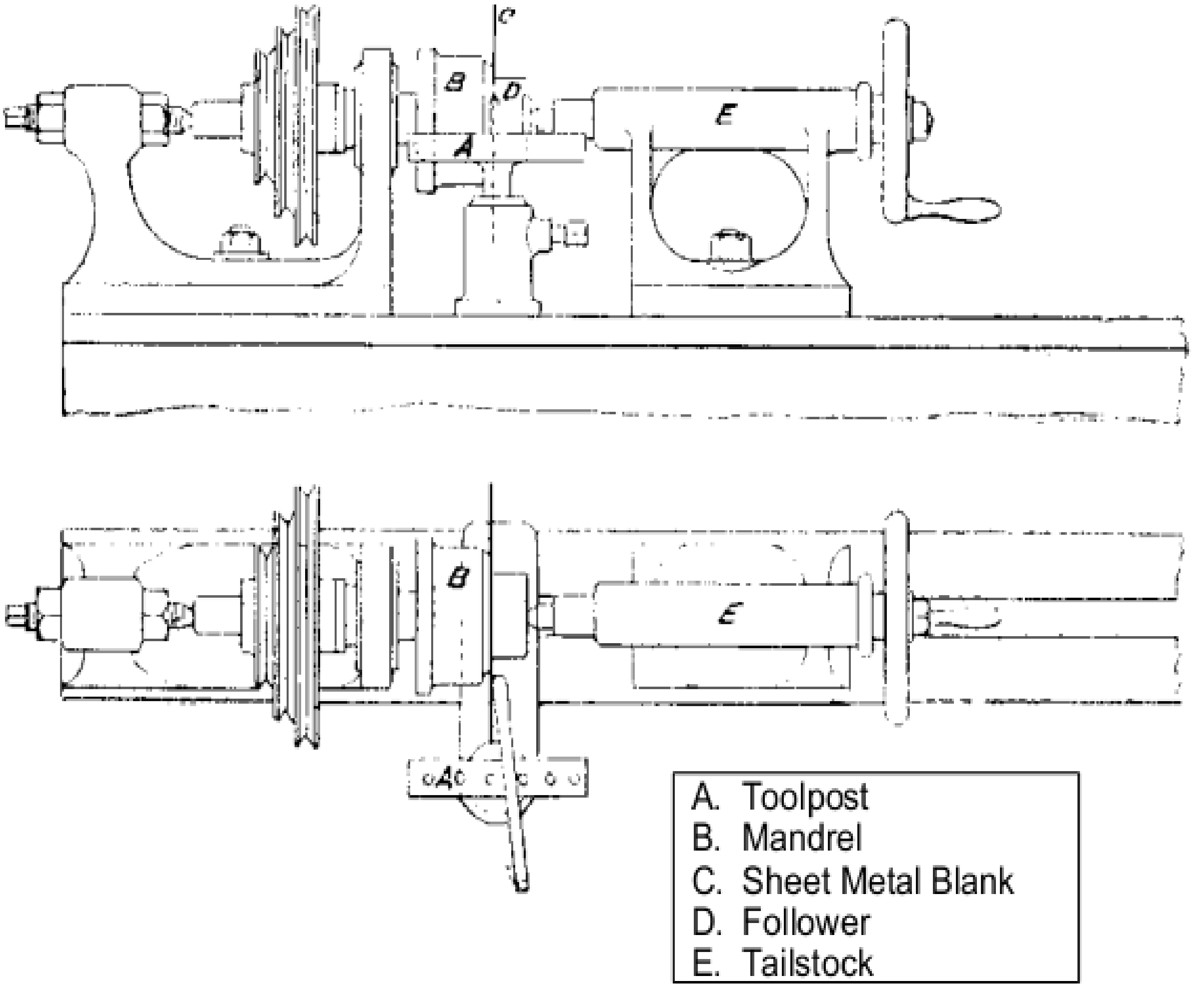


Fig: 19 Lathe Machine

3.2 SPARK PLUGS

- The spark plug is quite simple in theory. It forces electricity to arc across a gap, just like a bolt of lightning. The electricity must be at a very high voltage in order to travel across the gap and create a good spark. Voltage at the spark plug can be anywhere from 40,000 to 100,000 volts.
- The plugs must have the correct "reach", or length of the threads, diameter, sealing method, and heat range.

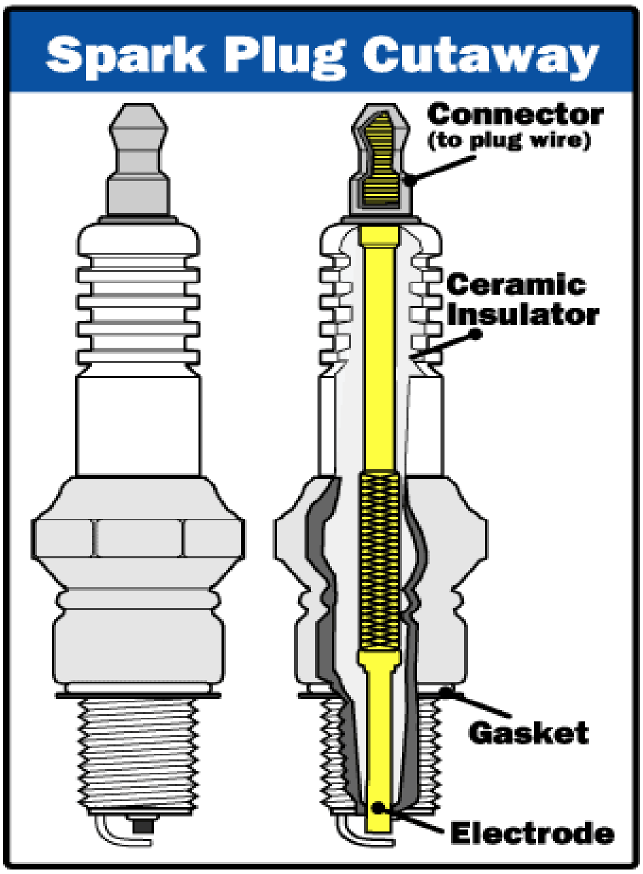


Fig: 20 Spark Plug

3.3 SPARK PLUG CAP:

The main function of spark plug cap is to hold the spark plug in the cylinder head or engine head. Especially it is used in (EFI) petrol engine or CNG engine gasoline engine. Mainly the aluminum materials are used in spark plug cap.

Mainly there are two types of spark plug holding caps are used in automobile engine,

1. Long thread type spark plug holding cap
2. Short thread type spark plug holding cap

In this experiment project we have manufactured both types of spark plug holding cap which is shown below.

Fig: 21 Spark plug cap

3.4 EXPEREMENTAL PROCEDURE

PROCESS PARAMETER:

TECHNOLOGICAL PARAMETERS

* Diameter of the sheet metal is 80mm
* Thickness of the sheet metal is 0.50mm
* Height of the cylindrical (spark plug holding cap):
  Exp. No.1 is 60mm & Exp. No. 2 is 110mm

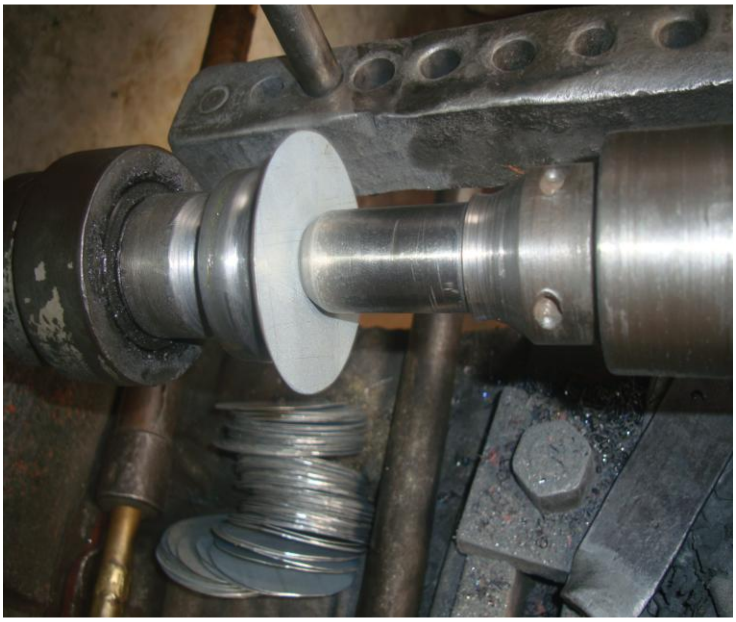
EXPLOTING PARAMETERS

* Thickness distribution
* Surface smoothness

3.5 MANUFACTURING PROCEDURE OF A SPARK PLUG CAP ARE AS FOLLOWS:

Step: 1

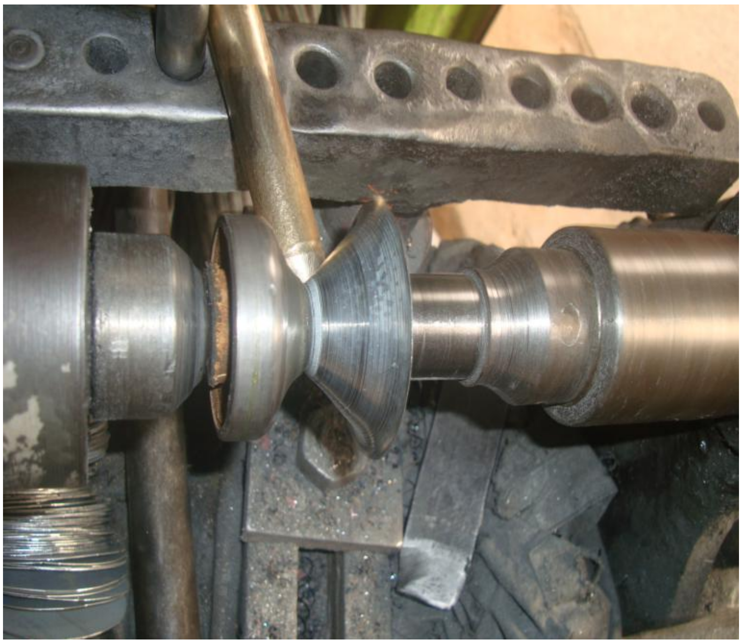
Step:1 At first from a 0.50mm thickness sheet metal a work piece was cut by the electrical cutting machine. Aluminum metal has been used as the work piece material of a circular sheet according to requirement.



Step: 2

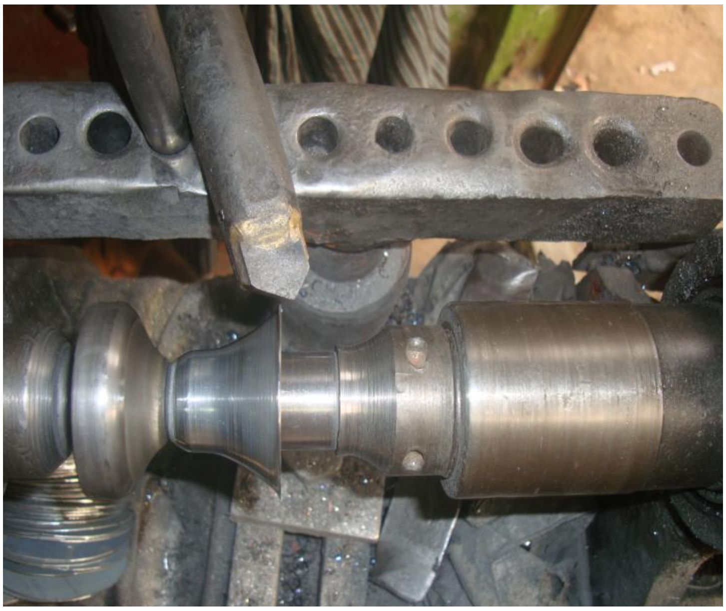
Step:2 &2(a) Then fix up the circular sheet metal onto the mandrel of a Lathe machine.

Step: 2(a)

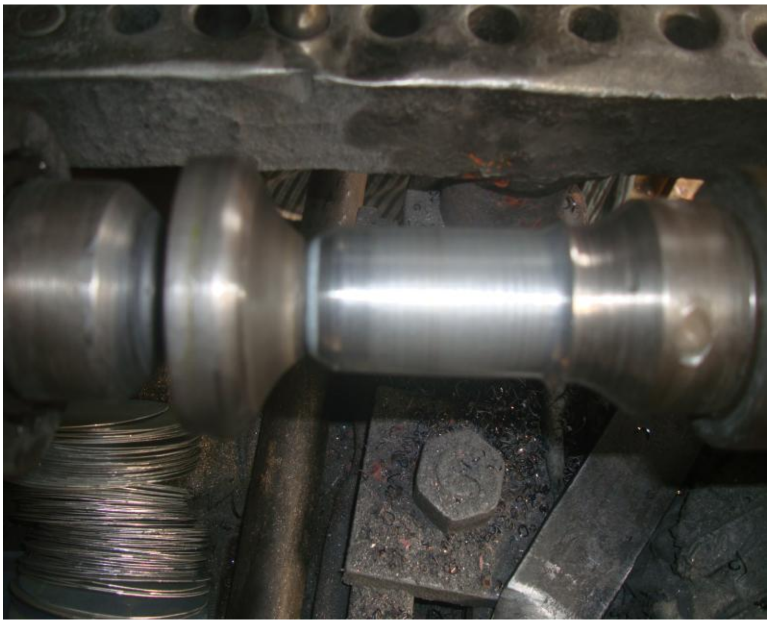


Step: 3

Step:3 Start the Lathe machine and push the circular sheet by a handle.



Step: 4



Step: 5

Step: 5 It is the ending position of the spark plug holding cap onto the Lathe machine. Throughout the operation verniercalipers was used to measure the dimension during the experiment.

Thus the full set-up was developed properly.

Step:6

Step:7

Step:8 Step:9

Step: 6to9 Are final product of the spark plug holding cap.

3.6 RESULT AND DISCUSSION OF A SPARK PLUG CAP:

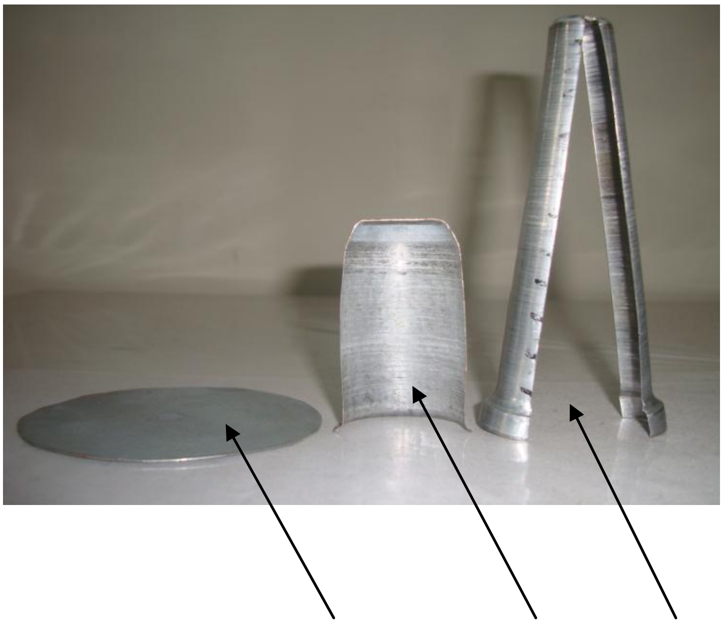


Fig: 22 Cross section of the spark plug holding cap

SPARK PLUG HOLDING CAP EXPERIMENT NO. 1

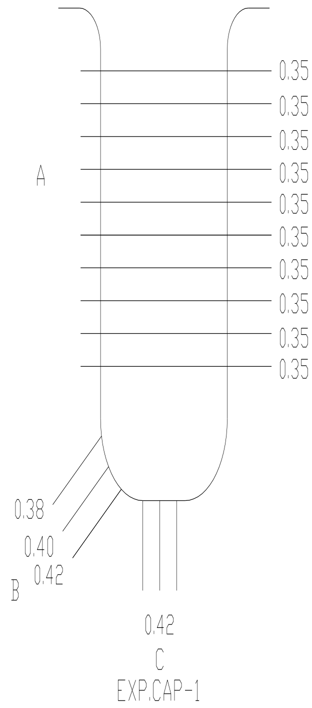
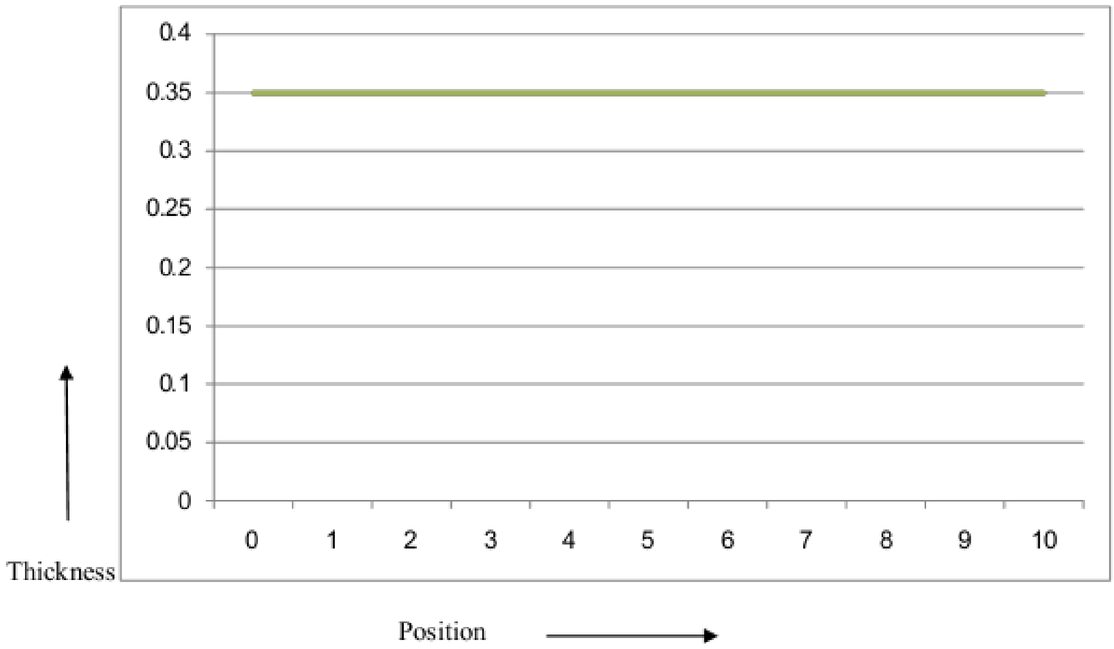


Fig: 23 Spark Plug Holding Cap Experiment No. 1

EXPERIMENT NO.1-A

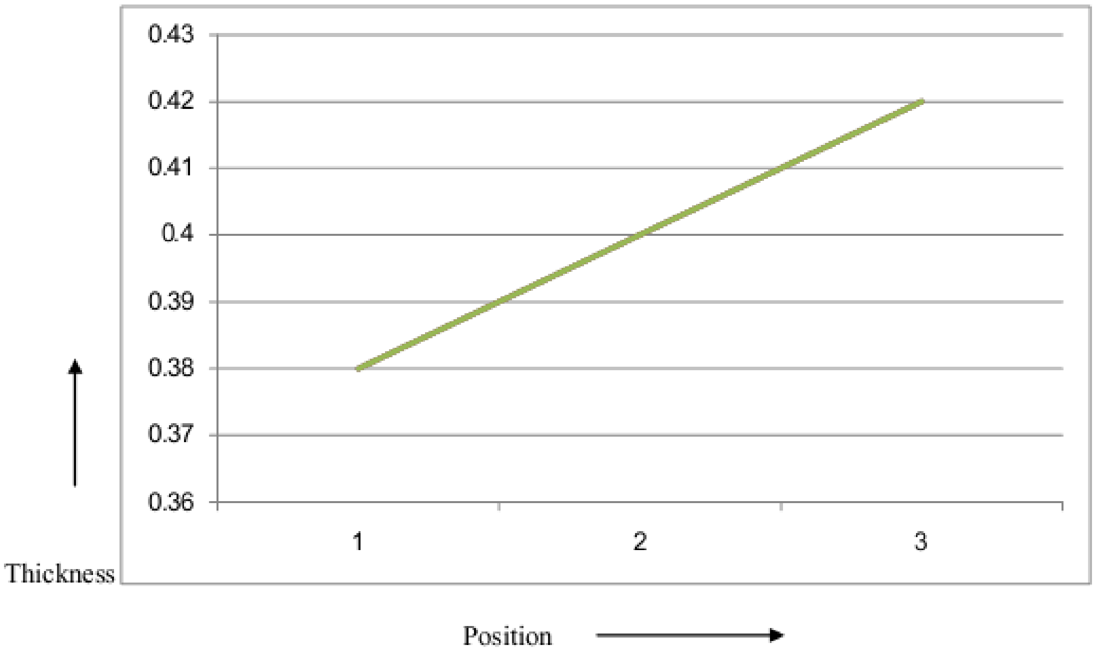
Thickness vs. Position



SECTION 1A. In this plot thickness is straight because in A section we have divided 10 position and thickness got the same in every 10th position which is shown in Fig 23.

EXPERIMENT NO.1-B

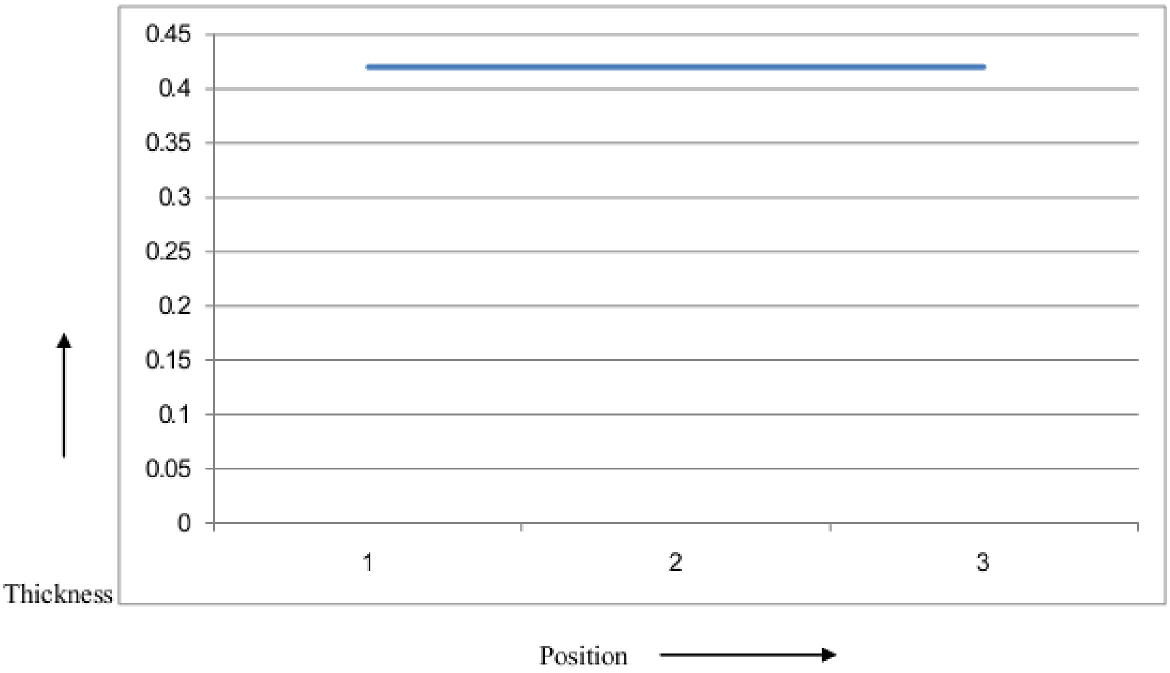
Thickness vs. Position



SECTION 1B. In this plot thickness is not straight because in the B section we have divided 3 position and thickness did not get the same in every 3 position(which is shown in the Fig: 23.) due to curve or circle the thickness has been varied somewhat.

EXPERIMENT NO.1-C

Thickness vs. Position



SECTION 1C. In this plot thickness is straight because in the C section we have divided 3 position and thickness got the same in every 3 position (which is shown in the Fig: 23).

SPARK PLUG HOLDING CAP EXPERIMENT NO. 2

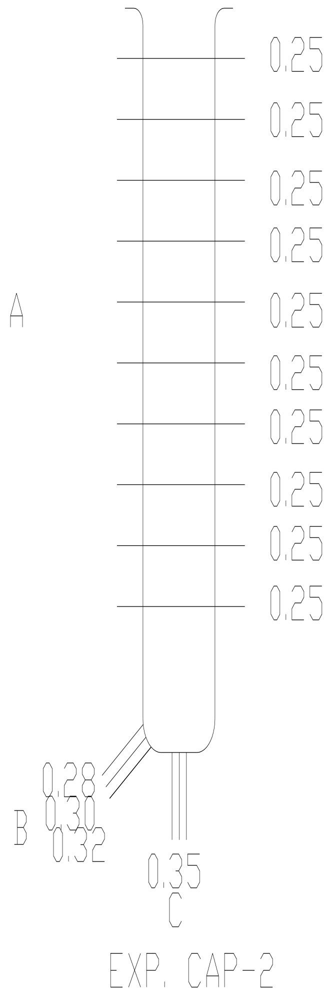
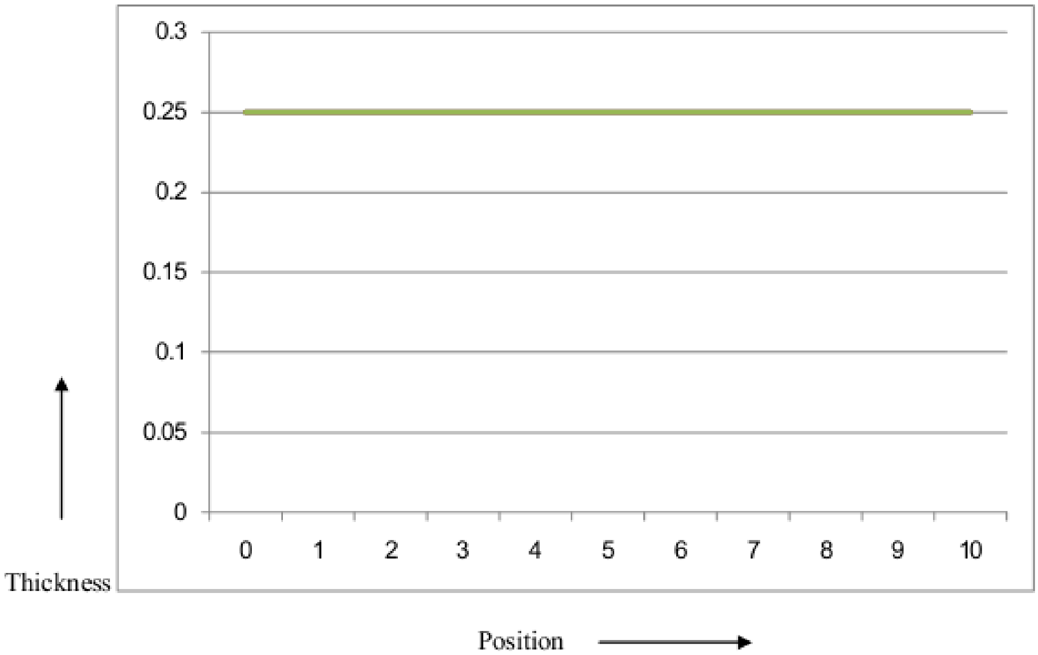


Fig: 24 Spark Plug Holding Cap Experiment No. 2

EXPERIMENT NO.2-A

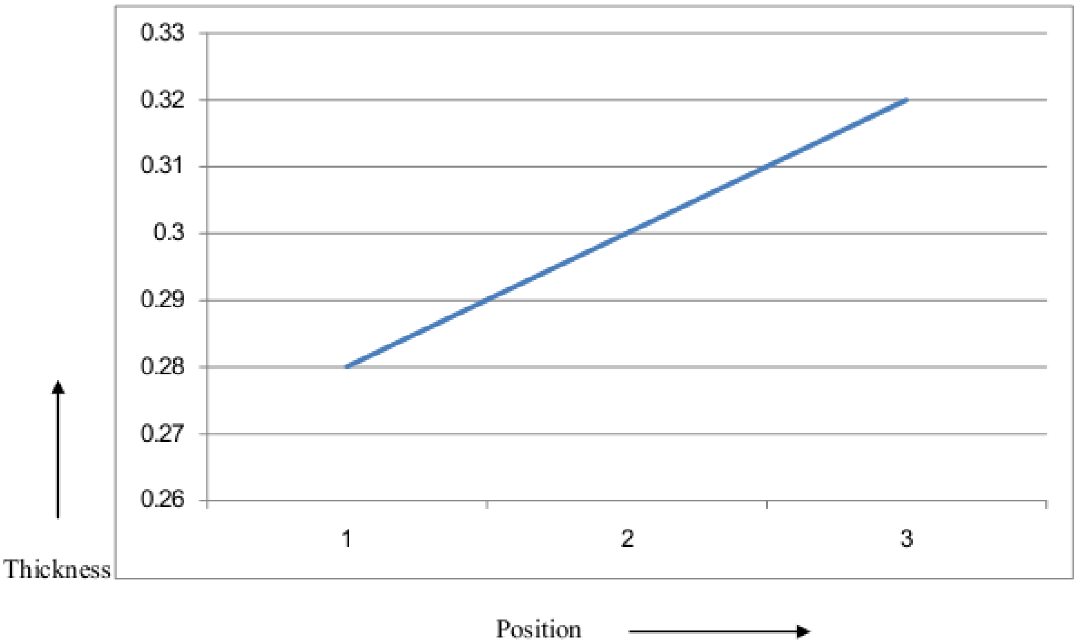
Thickness vs. Position



SECTION 2A. In this plot thickness is straight because in the A section we have divided 10 position and thickness got the same in every 10th position which is shown in the Fig: 24.

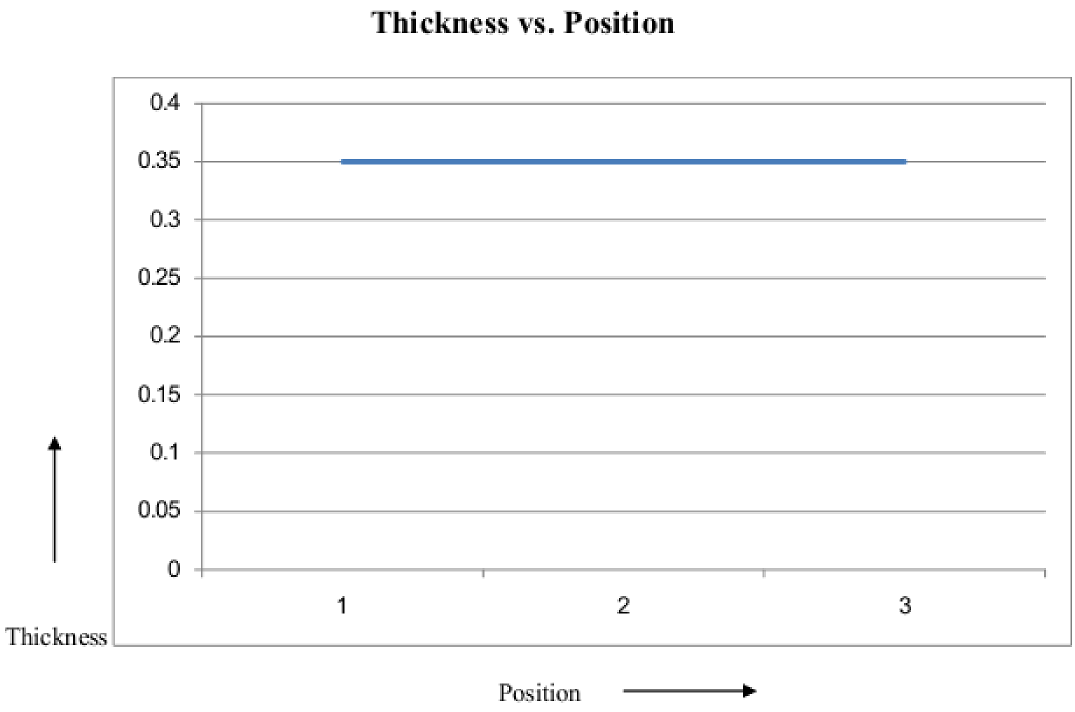
EXPERIMENT NO.2-B

Thickness vs. Position



SECTION 2B. In this plot thickness is not straight because in the B section we have divided 3 position and thickness did not get the same in every 3 position(which is shown in the Fig: 24.) due to curve or circle the thickness has been varied somewhat.

EXPERIMENT NO.2-C



SECTION 2C. In plot section thickness is straight because in the C section we have divided 3 position and thickness got the same in every 3 position (which is shown in the Fig: 24).

RESULT & DISCUSSION

Result is given under the above plot

DISCUSSION

1. The length of Experiment No.1 is smaller than the length of Experiment No.2 that's why the length vs. diameter of both are different.
2. The thickness of Experiment No.1 is bigger than the thickness of Experiment No.2 that's why the length vs. thickness of both are different.
3. Both of the final products thickness and diameter somewhat varied during the use of handle.

CHAPTER FOUR

RECOMMENDATION AND FUTURE WORKS

4.1 Recommendation:

- For the development of less deformed sheet metal structure this spinning process will be useful.
- The set-up is easy to prepare also
- Cost is less not so much high.

4.2 Future works

In the future this process can be more developed by applying the proper mandrel in the Lathe machine specially for preparing the spark plug holding cap.

Also by testing the distribution load and pressure distribution the effect can be modified in various aspects.

4.3 CONCLUSION

This article has described two forming techniques, manual spinning and power spinning, for forming seamless metal components. The equipment for both of these two spinning techniques is based on lathe technology, with appropriate modifications for the components that are being formed. A wide range of components can be produced using these two metal spinning techniques with relatively simple tooling. Metal spinning is very competitive with other forming processes, such as pressing and deep drawing; it is a highly flexible forming technique. Metal spinning can be operated economically to produce complicated parts for single applications, low-volume production, and mass production. Manual-metal-spinning and power spinning processes are very flexible and lend themselves to broad automation. Machine design changes, innovations in control systems, and process developments have led to improvements in all aspects of metal-spinning technology since the 1980s. Manual spinning is generally suitable for low-volume production of components. This article has described process technology, equipment, and tooling for both manual spinning and power spinning. Power spinning can be used to form large parts (up to 6 m, or 20 ft, in diameter); there is little scrap material, and the forming operation can be completed quickly. A wide range of shapes can be produced with relatively simple tooling. Power spinning is particularly suited to cones and hemispheres. Other components that can be produced by metal spinning range from small hardware items made in large quantities (such as metal tumblers and automotive components) to large components for high-performance aerospace applications in low-volume production (such as rocket engine casings and missile nose cones). Other examples of metal components that are spun include trophies, kettles, kettle drums, cymbals, tank ends, centrifuge parts, pressure bottles, ventures, radar reflectors, parabolic dishes, wheel discs, and wheel rims. For these types of complex geometries, manual-metal-spinning and power-spinning techniques are generally preferred over pressing and deep drawing; the advantages of spinning include flexible production, relatively low tooling costs, and short setup times.

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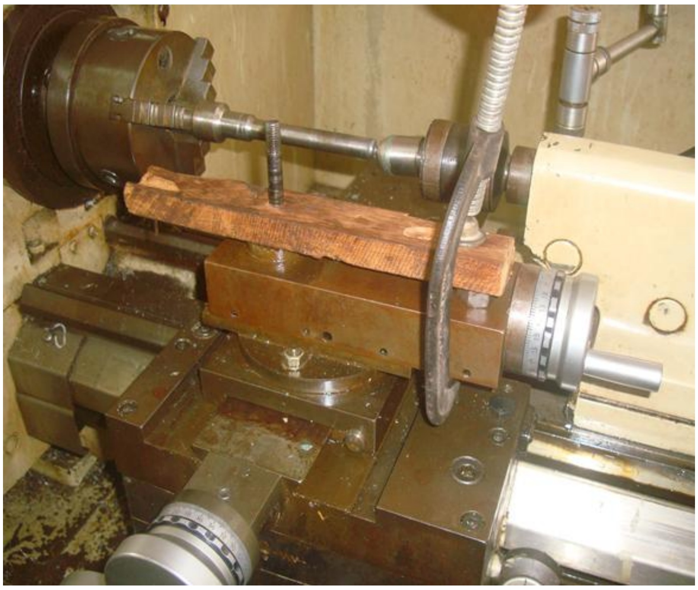
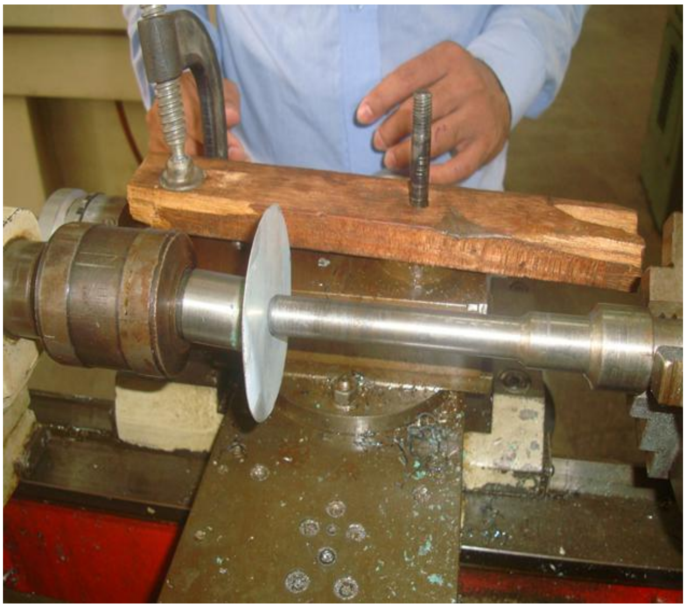
APPENDIX



Step:1

Step:2



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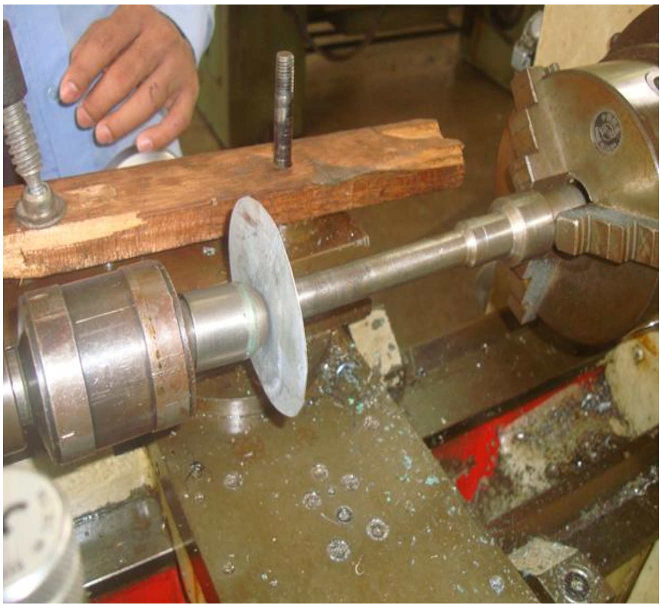


Step:4

Step:5 **Step:6**

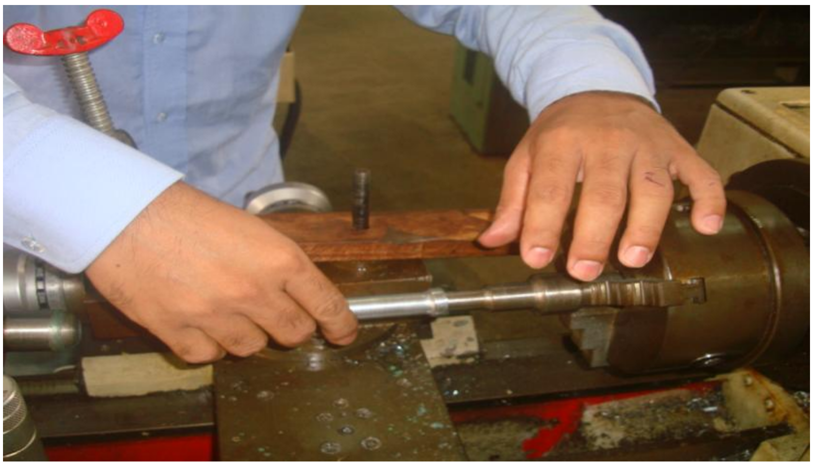
Step:7 **Step:8**

Step:9

Step:10

Step:11

Step:12



Step:13

Step:14 **Step:15**

Step:16 **Step:17**

Step:20 **Step:21**

Step: 22