A

PROJECT REPORT

ON

"Design and Development of Metal Spinning Machine."

Submitted in partial fulfilment of the requirement for the degree of Production Engineering course of Savitribai Phule Pune University

Submitted By

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NASHIK- 422003

(2020-2021)

CERTIFICATE

DEPARTMENT OF PRODUCTION ENGINEERING

K. K. WAGH INSTITUTE OF ENGINEERING EDUCATION AND RESEARCH,

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The project report entitled

"Design and Development of Metal Spinning Machine"

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In partial fulfilment of the requirement for the award of Degree of Bachelor of Production Engineering course of Savitribai Phule Pune University, during the academic year 2020-2021

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CERTIFICATE

This is to certify that Dhande Pratik Nitin, Ghule Shubham Rajendra, Kshirsagar Tejas Sanjay, Palhal Sagar Bharat *have successfully completed the project work on*"Design and Development of Metal Spinning Machine." *in partial fulfillment of the bachelors degree in PRODUCTION ENGINEERING during the academic year 2020-2021.*

PRINCIPAL

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We would like to thank our department for supporting us during this semester and encouraging us to be innovative and backing us in everything we did.

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ABSTRACT

Metal spinning is one of the oldest methods of chip-less formation. Spinning has gradually matured as a metal forming process for the production of engineering on the parameter and their interdependence. The parameters in the metal spinning are workpiece parameter, tooling parameter and process parameter, with the help of these three parameters improve the mechanical property and quality of product. The spinning process also enables components to be produced with both improved mechanical properties of almost 2 to 2.5 times their value in the raw material condition as well as with high dimensional accuracies and surface finishes. Such components mostly find application in the aircraft and missile industries which require a high strength to low weight ratio for their component.

Metal spinning is a method of forming rotationally symmetrical sheet metal parts. Metal spinning does not involve removal of material, as in conventional wood or metal turning, but forming of sheet material over an existing shape. It is also known as spin forming or spinning or metal turning most commonly, is a metal working process by which a disc of metal is rotated at high speed and formed into an axially symmetric part. In this project the basic principle of Metal Spinning is used. For the application of process slight desired changes have to be made in a regular lathe machine. By implementing the changes in the lathe machine the assembly thus can be used to manufacture products. Main objective is to achieve similar working process as that of the spinning in regular lathe machine by doing its slight modification

Selection of the spinning process plan is the primary issue in spinning processing. Practical experience shows that, the most desirable plan can be determined only through taking into account of comprehensive factors such as the structure shape and size of spinned pieces, product quality, rough material and surface conditions, the production performance and usage of equipment as well as the economical efficiency of production and other factors, after the spinning production task has been fixed. Otherwise, it will directly affect the spinning quality of the pieces.

Keywords: Sheet metal spinning, Metal forming, Rotationally symmetrical, Workpiece parameter, Tooling parameter and Process parameter

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CHAPTER 1: INTRODUCTION

1.1 MANUFACTURING PROCESSES AND CLASSIFICATION[1]

Manufacturing processes are the steps through which raw materials are transformed into a product. The manufacturing processes can be broadly classified into three categories viz. shaping, joining and finishing processes as shown schematically in Fig 1. The selection of a particular process from a wide range of choices for a given application requires a hierarchical classification of the processes. For example, Fig 2 depicts how the shaping family can be expanded in different classes such as casting, deformation, moulding, composite and powder processing, and prototyping. Next, moulding as a class can be enlarged into a number of member processes such as compression, rotational, transfer, injection moulding, etc. Lastly, each member process can be identified with a number of attributes, which would facilitate the selection of a member process for a given material, dimension, level of requisite tolerances and so on. Similarly, Fig 3 depicts how the joining and machining family can be expanded in different classes and actual processes. A brief description of the three broad categories of the manufacturing processes and the corresponding classifications are outlined in the following: [1] and [2].

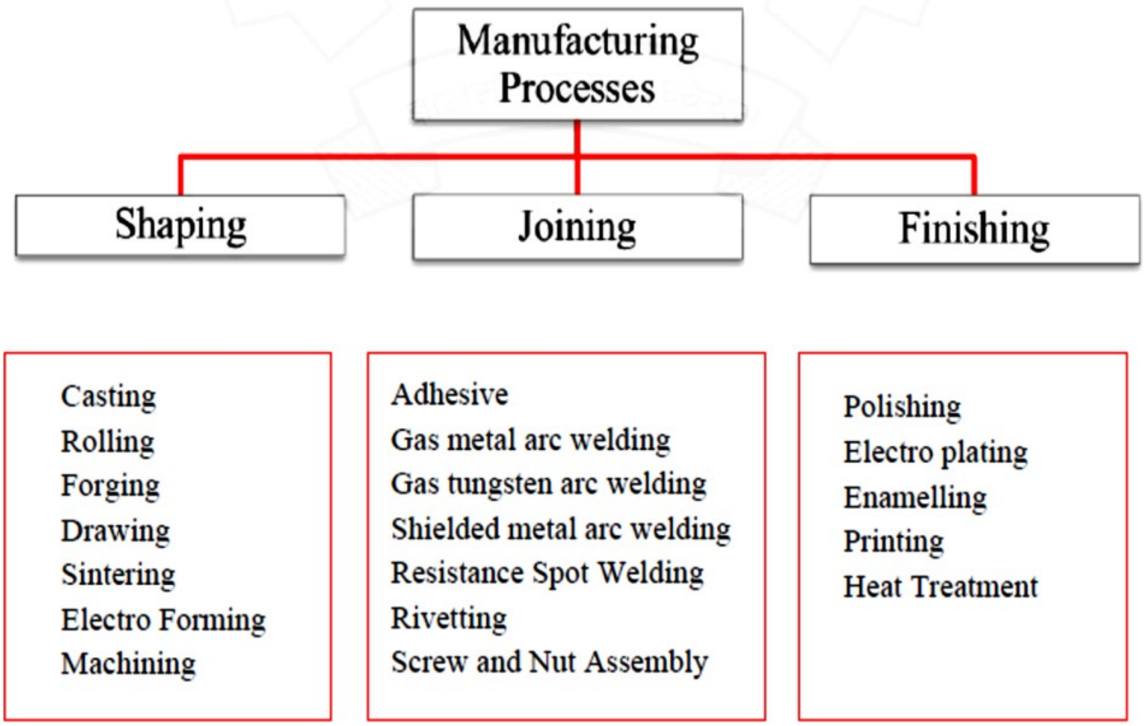

Fig 1.1 Different Classes of Manufacturing Processes[2]

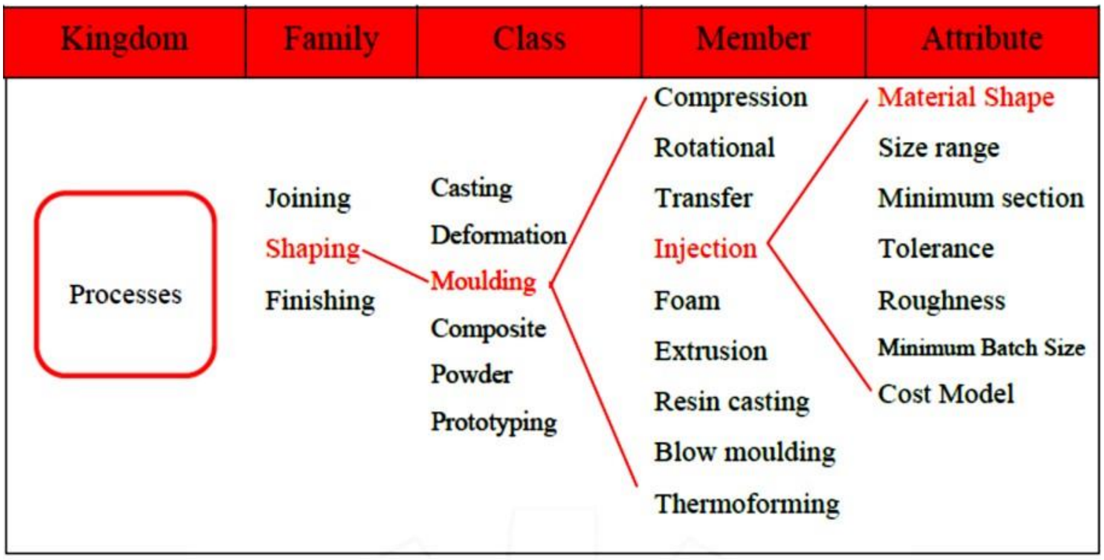

Fig 1.2 Taxonomy of Process with Part of Shaping Family[3]

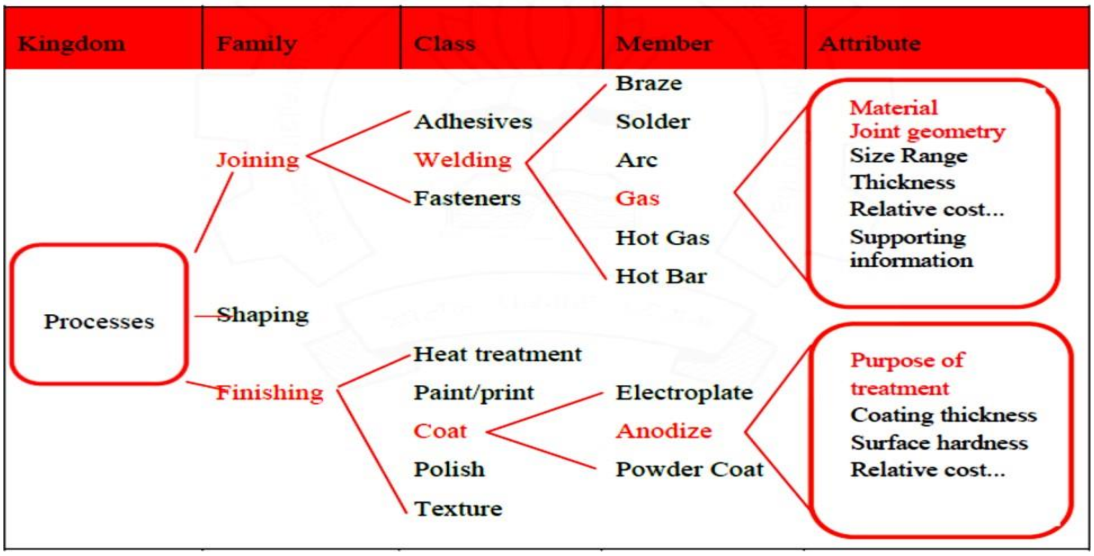

Fig 1.3 Taxonomy of Processes with Part of the Joining and Finishing Family[4]

1.1.1 SHAPING PROCESSES

The shaping processes[1] are referred to those that use a certain raw material and shape it to a final part. Casting, molding, powder material processing, primary and secondary material forming, machining are typical examples of shaping processes. A short exposure of different shaping processes is enlisted below

CASTING PROCESSES

Most of the manufactured parts start their journey with the casting process. In a typical casting process, metal is first heated in a furnace until it melts and then the molten metal is poured into a mold so that the liquid metal takes the shape of the mold cavity, which is the final shape of the part. Once the liquid metal in the mold cavity solidifies, the mold is broken opened to take the final part out of the mold cavity.

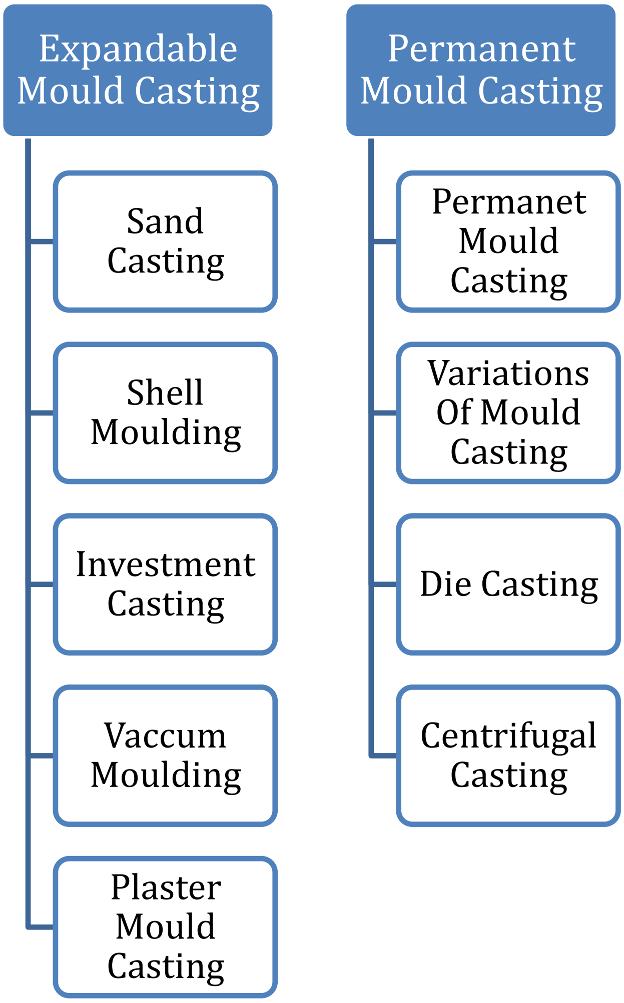

Fig 1.4 Classification of casting processes

1.1.2 JOINING PROCESSES

Though shaping is one of the most important processes and can produce a wide range of components, it is often deficient in making a complete product due the complexity associated with the shape and functions. So, joining of simple pre-shaped parts into a fully functional structure is necessary. Welding, brazing and soldering, fastening, and adhesive bonding are the most commonly used processes in joining. Even after joining, further processing may be required to enhance the mechanical properties and aesthetics of the final assembled part or component to meet specific operational conditions.

A. Mechanical Joining Processes

The permanent joining processes, which are mechanical in nature, are, in principle, derivatives of the basic metal working processes. These are often referred to as fasteners. The most common mechanical joining methods are rivet, nut and bolts, staple, seam joint etc. Fig 9 schematically depicts a number of mechanical joints.

B. Solid State Joining Process

In solid state joining processes, the bonding between the assembled members occurs through adhesion and / or diffusion across the original joint interface. However, adhesions between the two surfaces are difficult due to the presence of surface contaminants such as oxide layers, adsorbed gas films, residual lubricants, etc. Various techniques are adopted to promote the adhesion between two surfaces such as:

- Relative movement of faying surfaces under an axial force that helps to break up surface films facilitating the exposure and mating of clean surfaces,
- Plastic deformation of the contacting bodies leading to growth and extension of the contacting surfaces that would result in rupture of interfacial contaminants and exposure of fresh, clean surfaces, subsequently, creating a solid-state weld,
- Softening of contacting interfaces by localized heating, applied externally or generated in- process, to promote easy plastic deformation and / or inter-atomic diffusion creating a solid- state bond.

C. **Liquid State Joining Process**

The liquid state joining processes involve localized melting and solidification of workpiece materials with or without the addition of external filler material. The liquid state joining processes are commonly referred to as fusion welding. Based on the characteristics of the external filler (electrode) material, the welding processes can also be classified as consumable electrode and non- consumable electrode welding processes.

Some of the common fusion welding processes are listed below:

- ❖ Shielded Metal Arc Welding process (SMAW)
- ❖ Gas Metal Arc Welding Process (GMAW)
- ❖ Submerged Arc Welding Process (SAW)
- ❖ Gas Tungsten Arc Welding Process (GTAW)
- ❖ Plasma Arc Welding Process (PAW)

1.1.3 SURFACE TREATMENT METHODS

The surface treatment processes are used to improve the properties of the surface only. In many applications, it is necessary to harden the surface to prevent abrasive wear. Different types of hardening methods such as quenching, induction hardening, carburizing, nitriding, physical vapor deposition (PVD), chemical vapour deposition (CVD) are some of the commonly used surface treatment methods. Similarly, thermal coating like cladding, thermal spraying, hot dipping etc. surface treatment processes such as painting, electrolytic coating, etc. and conversion coating like oxidizing, phosphating, chromatin etc. are also employed to improve surface properties.

1.2 MATERIAL FORMING[5]

Metal forming, a subset of fabrication, involves the reshaping of metals while still in the solid state. By taking advantage of the plasticity of certain metals, the forming process makes it possible to move a solid piece of metal from its current shape into the desired form. The metal forming process accomplishes this without melting the material, thereby avoiding any potential difficulties in the handling of molten metal or the integrity of molded products.

Types of Bulk Metal Forming: Bulk metal forming[2] involves materials with a low ratio of surface area to volume, like bars, tubes, or billets. Bulk forming encompasses techniques like roll forming, forging, extrusions, castings, and drawing.

- **Rolling** [2]involves sending metal stock through a set of rollers, which deform the original stock and output it into the shape needed. Sheets, strips, rails and other similar shapes can be produced by rolling. This method produces tight, repeatable tolerances, high strength metal, and little or no scrap.

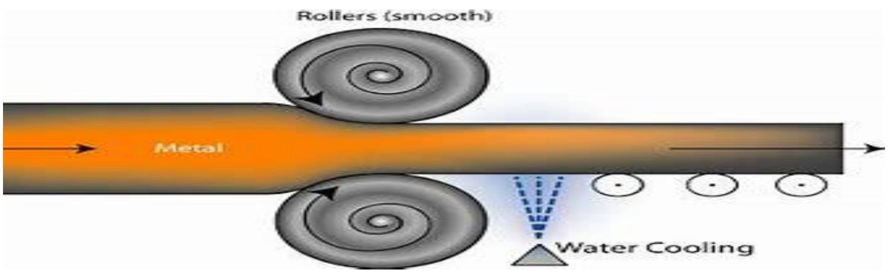

Fig. 1.5 Rolling Process [6]

Forging[2] uses presses, hammers and other compressing devices to shape metal stock. Parts made by the cold forging process are often referred to as cold-headed parts. Often used for aerospace and automotive applications, forging's main advantages come from the low amount of secondary services needed and the strength and hardness of the end product.

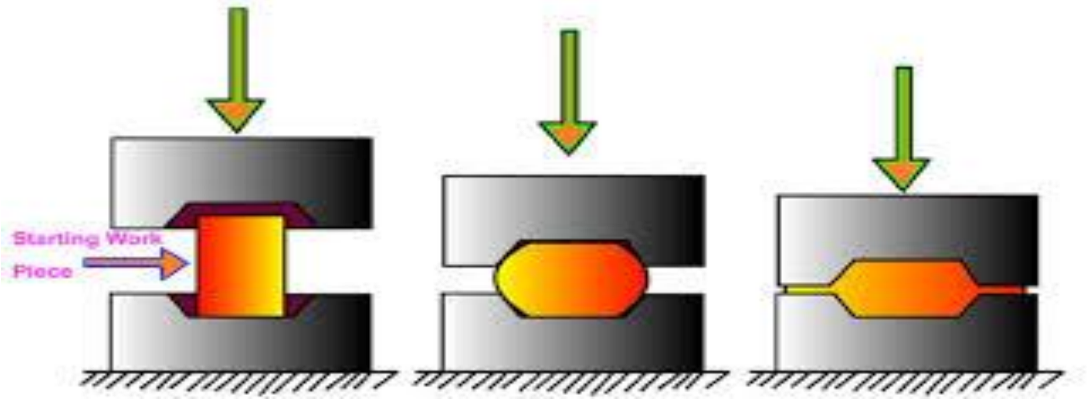

Fig. 1.6 Forging Process[7]

- **Extrusion** [2]is a process whereby stock is forced through a die and emerges as a tube with a nearly identical cross-section to the die. The method of forming allows for hollow shapes without seam welding as well as complex cross sections.

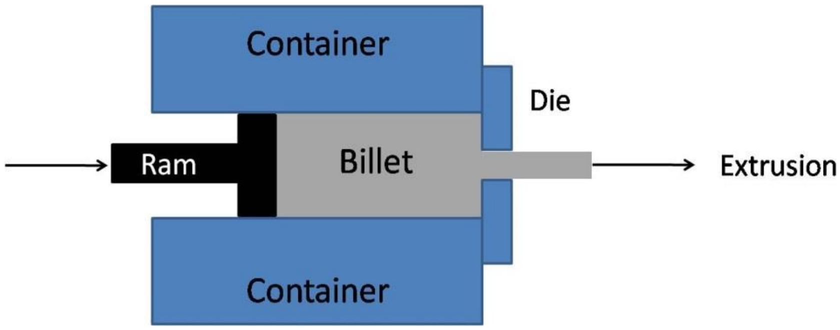

Fig. 1.7 Extrusion Process[8]

- **Casting[2]** is performed by pouring molten metal into a die or mold. Its advantages run toward complex parts and the wide range of alloys that can be used for it.

- **Drawing[2]** resembles extrusion, except that the workpiece is pulled, not pushed through the die. While drawing is done on thicker pieces of metal, it should not be confused with deep drawing, which is a process applied to sheet metal.

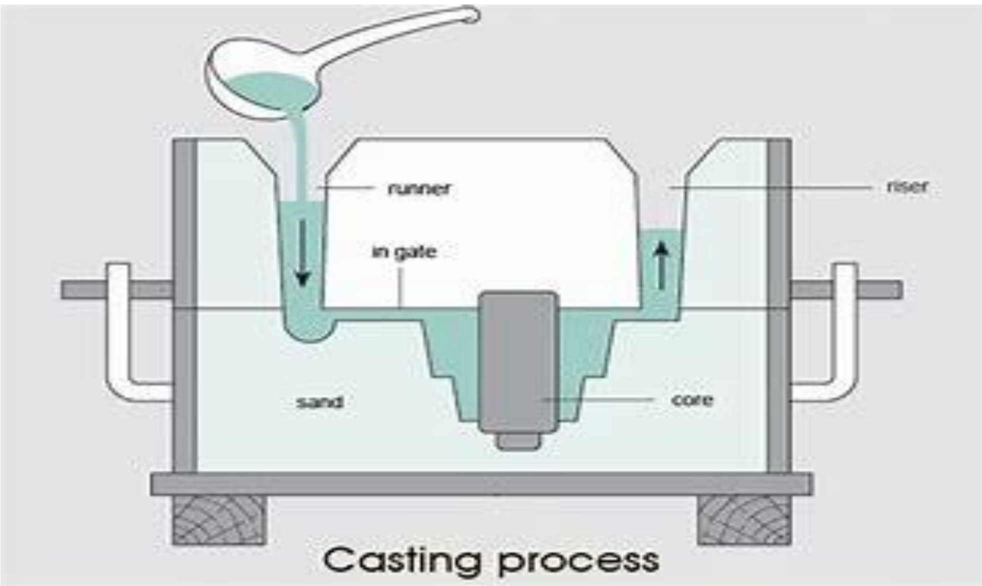

Fig. 1.8 Casting Process [9]

Types of Sheet Metal Forming:

Sheet metal forming uses metal forms with a high surface area such as plates and sheeting to form products. This can include deep drawing, bending, shearing, and stamping.

Deep drawing[2] involves drawing plate or sheet into the needed shape to the point that the final result has a height equal to or larger than its width. This method is good for complex geometry products, as well as fast production.

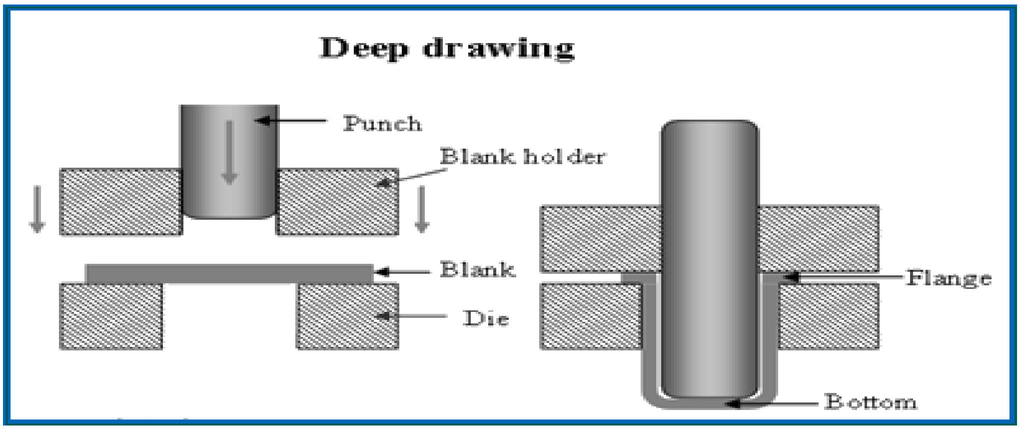

Fig. 1.9 Deep Drawing [10]

Bending[2] involves the reshaping of metal around a linear axis, and is usually accomplished through a press brake. Bending provides less residual stress than roll forming.

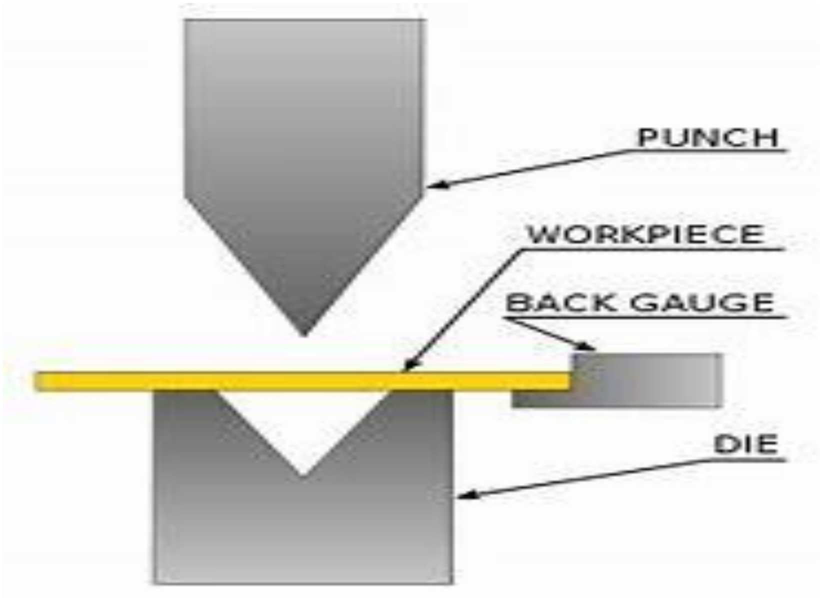

Fig. 1.10 Bending Process [11]

Metal Forming Tools

- **Presses**, which create stampings. Presses shape metal by crushing it between a top and bottom (the bottom is called the bed). They come in mechanical, hydraulic, and pneumatic types.
- **Benders** come in different varieties depending on whether the metal is a sheet or a bulk material. Press brakes create V- and U-shaped bends in sheet metal by pressing the sheet down into a die with a die block. There is also tube and bar bending equipment in manual and machine types.
- **Roll forming machinery** flattens and thins metal by running it between two rollers, and is often used to curl it into coils. Roll forming machinery can come in several different types depending on the need, including machines that can process multiple workpieces or that have multiple sets of rollers for a single piece.
- **Dies** are a form to shape raw metals. In addition to being used for stampings and bending, dies are also used for drawing and extrusion as metal is pulled or pushed through them to be shaped.
- **Extruders** force metal through a die to shape and strengthen it. Extruders can use direct, indirect, hydrostatic, lateral, or impact methods to extrude the metal.

- The opposite of extruders, **Drawing machines** pull metal through dies or draw plates to thin and strengthen it. Draw benches are also used for the drawing process.

Metal Forming Applications

Metal forming is used to create all manner of products, including tubes, pipes, metal sheets, fasteners, and wire. Many of the metal objects we encounter in everyday life, from thumbtacks to file drawers, were likely produced by one or more metal forming operations. Industrial metal forming is commonly used across multiple sectors, including the automotive industry, which uses metal forming for door frames and bumpers. It's also used in aerospace, which forms metal for engine parts, blades, and structural parts. Metal is also formed for architectural purposes, such as decorative molding or roof parts.

1.3 Metal Spinning Process

1.3.1 Introduction to Metal spinning

Metal spinning, also known as **spin forming** or **spinning** or **metal turning** most commonly, is a metalworking process by which a disc or tube of metal is rotated at high speed and formed into an axially symmetric part. Spinning can be performed by hand or by a CNC lathe.

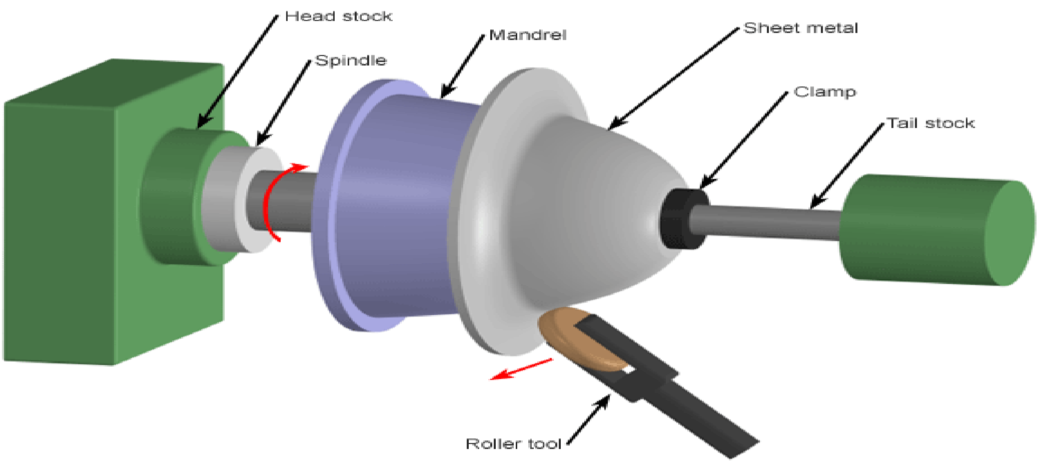

Fig. 1.11 Metal Spinning Operation [12]

Spinning is a sheet metal forming process in which a metal blank is pressed over a rotating chuck or form mandrel with the help of a pressing tool to obtain an axisymmetric hollow shell. The sheet metal parts that have circular cross-section can be made by this process. Generally, the shapes produced by spinning can also be manufactured by drawing, compressing or flanging. However, spinning is usually used for forming large parts that require a very large drawing process or when various shapes are needed but only a small number of each shape is required.

Metal spinning is one of the oldest methods of chipless forming, but over the years, this process has lost ground to other forming processes such as deep drawing and ironing. However, due to the inherent advantages and flexibility of the process such as simple tooling and low forming loads, plus the rapid emerging trend in modern industries towards near net shape manufacturing of thin sectioned lightweight parts, spinning has undergone a renaissance in recent years and has developed into a versatile process for producing lightweight components

Spinning is commonly known as a process for transforming flat sheet metal blanks, usually with axisymmetric profiles, into hollow shapes by a tool which forces a blank onto a mandrel. The blanks are clamped rigidly against the mandrel by means of a tailstock and the shape of the mandrel bears the final profile of the desired product. During the process, both the mandrel and blank are rotated while the spinning tool contacts the blank and progressively induces a change in its shape according to the profile of the mandrel. As the tool is applied locally on the workpiece, the total forming forces are reduced significantly compared to conventional press forming. This not only increases the possibilities in terms of large reductions and change in shape with less complex tooling, but also reduces the required load capacity and cost of the forming machine. In addition, spinning is also known to produce components with high mechanical properties and smooth surface finish.

1.3.2 Types of Spinning

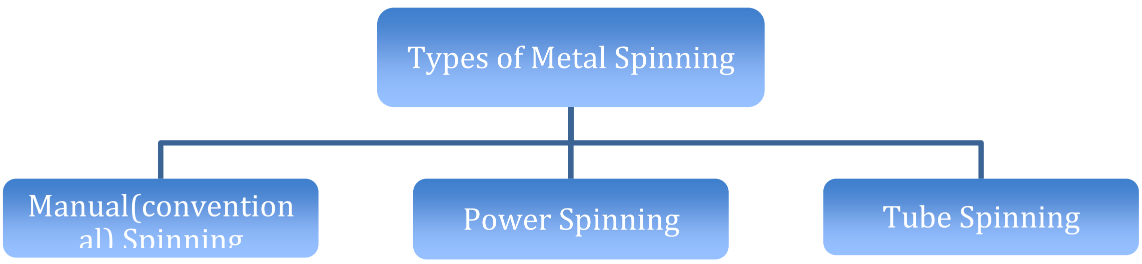

Fig.1.12 Types of Metal Spinning

1. **Manual (Conventional) Spinning**
    - Scissor Tool Manual Spinning
    - Underarm Tool Manual Spinning
    - Push-In Spinning
2. **Power Spinning**
3. **Tube Spinning**
    - Forward Tube Spinning
    - Reverse Tube Spinning
    - Internal Tube Spinning

1.3.3 Applications of spinning Process

Metal spinning is quick, efficient and precise, but typically doesn't have the versatility of deep drawing or pressing. Due to the nature of the process, metal spinning cannot create irregular shapes; however, for bell-shaped, spherical, and tubular forms, metal spinning is often highly cost-efficient. This is not a result of the high fixed cost of metal spinning, but of the relatively low variable costs.

Metal spinning is fairly flexible due to the ease of applying automation, which leads to faster lead times in producing short or long runs of a product. If a product doesn't require specialized tooling, turnaround can be as short as two to three weeks. These faster lead times also foster appeal for metal spinning as a quick and efficient production method for prototypes or one-offs. With the use of CNC machines, metal spinning can be highly competitive with other forms of metal product fabrication.

Manufacturers use metal spinning to produce lamps, spheres, vases, solid wood furniture and many other items. It also has alternate applications, such as the production of metal sculpture for artistic and design purposes.

Applications:

Metal spinning are used in a wide variety of applications and industries, here are some examples:-

Lightning:

Lighting fixtures use spun metal parts in a wide variety of ways. Louvres and shades to control light distribution, minimise glare and limit light pollution. Functional gear trays to hold components which can also form the main body of a fixture.

Lighting bollards use metal spinning for caps and glare control louvres. Metal spinning used for gear trays and decorative trim

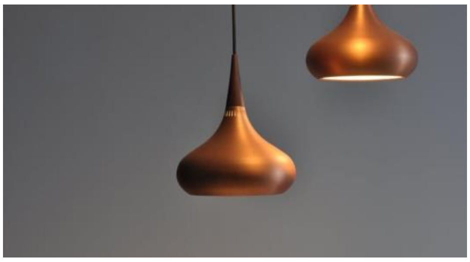

Fig. 1.13 Lightning Application [13]

Air Handling:

Metal spinnings find their way into a wide range of industrial applications such as fans covers for induction motors, process hoppers, funnels and mixing bowls. The need for cleanliness and resistance to harsh environments mean that stainless steel is an ideal material choice.

Fig. 1.14 Air Handling Application [14]

Industrial:

Metal spinning find their way into a wide range of industrial applications such as fans covers for induction motors, process hoppers, funnels and mixing bowls. The need for cleanliness and resistance to harsh environments mean that stainless steel is an ideal material choice. Stainless steel process hopper spinning. Stainless steel bowls formed by metal spinning.



Fig. 1.15 Industrial Application [15]

Architectural:

Metal spinning finds a wide range of uses in the built environment from decorative finishes such as building cladding and column bases to function items such as waste bins. Waste bins formed by spinning. Metal spinning used to form part of the base for bar tables and chairs



Fig. 1.16 Architectural Application [16]

Some more other examples of products from metal spinning.

- ❖ Bases, baskets, basins, and bowls
- ❖ Bottoms for tanks, hoppers, and kettles
- ❖ Canopies, caps, and canisters
- ❖ Housings for blowers, fans, filters, and flywheels
- ❖ Ladles, nozzles, orifices, and tank outlets
- ❖ Pails, pans, and pontoons
- ❖ Cones, covers, and cups
- ❖ Cylinders and drums
- ❖ Funnels and horns
- ❖ Domes, hemispheres, and shells
- ❖ Rings, spun tubing, and seamless shapes
- ❖ Vents, venturis, and fan wheels

1.3.4 Advantages and Limitations of Spinning Process

Advantages Of Spinning Process

The spinning process is usually used for forming large parts and when various shapes are needed but only a small number of each shape is required.

Some advantages are listed below:

(i) Comparable to Drawing Process: The spinning process is comparable to the drawing process for producing cylindrical, axisymmetric parts.

(ii) Economical Process: The spinning process uses the simple tools; hence it is economical for small lots.

(iii) Best Suited for Large Parts: Larger parts are much more easily made in spinning than by drawing.

(iv) Complicated Shapes Produced: The complicated shapes that are not feasible by the drawing process are easily produced by the spinning process.

(v) No Investment is Die Making: The spinning operation can be tried quickly and without any investment on new models as it requires no special tooling and die making.

(vi) No Finishing Operation Required: The spun parts require no finishing operation like bending trimming etc.

Limitations of Spinning:

(i) More Time Required: The time required to produce a cup is more in spinning than drawing process.

(ii) More skill Required: The spinning process requires more skill of operator as tool is manually passed against the metal blank.

(iii) Not suitable for large-scale Production: The spinning process is not suitable for large-scale production, as it consumes more time.

(iv) Strength: Although metal spun products are considered strong, in some cases when they are compared to other types of metal processing, they can be referred to as a weaker material.

(v) Snarl: Due to the nature of this process, snarling is more likely to occur when it comes to metal spinning, this means it may leave a small imperfection on the surface of the metal.

(vi) Difficulty with keeping the spinning consistent: When it comes to the metal spinning process, it can be more difficult to keep the spinning condition constant.

(vii) Increases the unevenness and imperfections: This type of process can also increase the unevenness and imperfections due to the speed of the spinning, this can also contribute to the strength of the product.

1.4 Parts Required:

We are Designing and Developing a Small Setup of Metal Spinning Machine using some tools, parts, lathe machines in our workshop. In this project we require Lathe machine, forming tools, Mandrel of different Shapes, Clamp for holding the workpiece, Sheet metal, etc.

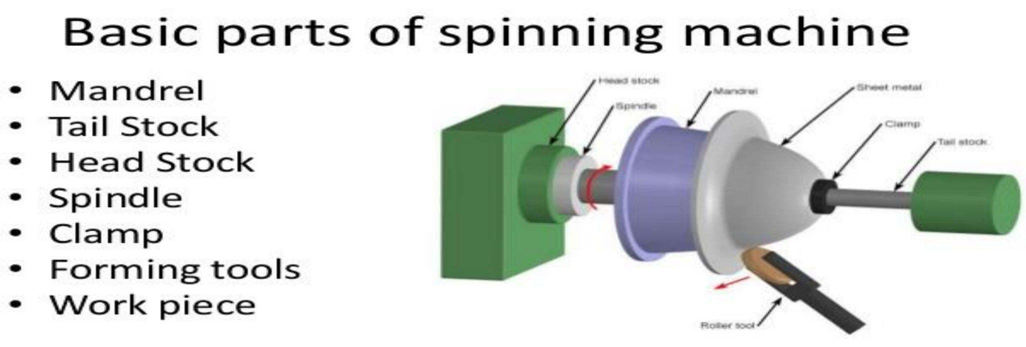

Fig. 1.17 Parts of Spinning Machine [17]

We perform a Manual (conventional) metal spinning Operation in this project. This project was to be carried out in our college workshop.

We have studied all the concepts of spinning operations. How the spinning is to be carried out and which metals are to be spined using this process? How much time is required to perform the operation? How to handle a tool while doing an operation? What difficulties do we face during machining? What is the right procedure to perform the operations? What results will we get after completing the whole setup? And finally, we have to conclude that how the spinning of metal is to be carried out?

Various researchers work regarding Metal Spinning process, material deformation, advancement of process are discussed below:

B.P. Bewlay and D.U. Furrer[18] 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, venturis, 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.

G. Sebastiani et.al.[19] investigated on Process Characterization of Sheet Metal Spinning by Means of Finite Elements**.** Within this work, sheet metal spinning was investigated by means of the explicit Finite-Element code LS-Dyna. The assessed model provides deeper insight in the distribution and evolution of stresses during forming operations where the latter was up to now neither covered by theoretical models nor previously conducted simulations. The stress distribution is not restricted to local zones, but only takes a characteristic shape within the whole blank. Apart from three brief disturbances, the denoted stress distribution remains in a steady state, only translating along with the tool contact. The theoretical model predicting radial tension and compressive hoop stresses for the rim-directed movement could not be verified. The stress distribution in the immediate contact zone incorporated bulging effects, which result in compressive stresses in the roller-facing and tensile stresses in the mandrel-facing surface. These stresses are found to be independent of the tool heading. Unique dynamic stress patterns evolve at the rim throughout the center directed movement. The toothed shape of the latter, similar to wrinkles, implies a corresponding pre-state to wrinkling. In this context, the absence of compressive hoop stresses in the outer rim seemingly introduces an excitement of the blank close to its current shape-dependent Eigenmode as an additional dynamic source of wrinkles. However, further investigations on wrinkling and Eigenmodes of the intermediary shapes of the workpieces are mandatory to thoroughly verify such a dependency

L. Wang and H. Long[20] analysed effects of roller path profiles on Tool Forces and part wall thickness variation in Conventional Metal Spinning.

a) FE analysis results indicate that the concave roller path produces the highest tool forces among four different roller path designs developed, i.e. combined concave and convex, convex, linear, and concave roller path profile. The lowest tool forces are generally observed when the convex roller path is used.

b) Using the concave roller path tends to cause the highest reduction of the wall thickness of the spun part, while the convex roller path helps to maintain the original wall thickness unchanged. A greater curvature of the concave path, a higher amount of thinning in wall thickness of the spun part would take place.

c) High in-plane tensile radial strains and low in-plane compressive tangential strains have been observed in the workpiece of the conventional spinning process. The dominated in-plane tensile radial strains are believed to be the main reason for the wall thinning. In addition, if concave roller path is applied, much higher tensile radial strains are produced, resulting in more decreasing of the original wall thickness.

d) Two pairs of oppositely directed radial bending effects have been observed in the workpiece during the conventional spinning. Furthermore, highest bending stresses are generated when concave roller path is used.

M. Shinde. et.al.[21] have described two types of metal spinning, metal spinning process and three important parameters like workpiece parameter, Tooling parameter, process parameter with the help of these three parameters we design metal spinning process. The benefits of metal spinning are

1. The tooling cost would be reduced for large components in the spinning process.
2. High accuracy obtained in the spinning process.
3. Good surface finish obtained in product.
4. Machinery and tooling set for metal spinning is simple.
5. The mechanical properties of raw material were increased by 2 to 2.5 times in the spinning process.

M. Tapase. et.al. [22] has proposed Metal Spinning- Design Consideration and parameter of spinning process and its terminology.Future scope for this research is to provide in depth guidance for the process study and designing the set up of spinning to minimize defects and failure of the component. By using this workpiece parameter, tolling parameter and process parameter good surface quality and good dimensional accuracy of the product is achieved. It also helps to improve the mechanical property of the spun component. Spinning processes also help to reduce the tooling cost of the process which will help to minimize the operating cost of the product.

D.K. Bhatt. et.al. [23] have done study on Incremental Sheet Metal Forming Process(ISF).The objective of this work is to understand some basics regarding the ISF process. Based on the review following conclusions are made, The ISF process is a flexible forming process, and it can be easily used for producing 3D complex shapes.The process parameters that are used have a major impact on the process conditions and the most significant are: Tool size, Tool rotation, material properties and sheet thickness.Material properties and the property evolution of the ISF parts are of interest for presenting the method for wider industrial use. The material property evolution affects the process itself, and is of importance for increasing process accuracy and control .Modelling property and process evolution offers means for control. Sheet thinning of the formed part has been proposed as a drawback for the process.The properties of incrementally formed products as compared to other forming methods are of interest when introducing this new method for wider use. Despite its shortcomings, ISF may be considered as a viable alternative to traditional sheet forming methods.

F. Klocke and C. Brummerb[24] presented Laser-assisted metal spinning of challenging materials**.** The demand for components made from high performance materials like titanium or nickel-based alloys as well as strain-hardening stainless steel is steadily increasing. However, these materials are usually difficult to form efficiently, thus conventional forming operations conducted on these materials are generally very laborious and time-consuming. By application of a high-power laser as heat source for the simultaneous heating of the workpiece during the forming process the forming limits of challenging materials can be enhanced significantly. Like that intermediate annealing steps which are conventionally needed can be eliminated. Furthermore, parts with complex shapes can be formed without the negative impact of conventional heating by means of gas burners. With the aim to make the technology applicable in industrial use, a test bench with the required flexibility has been developed. To be able to exploit the entire process performance of laser-assisted spinning and to introduce only the required amount of heat into the workpiece, a suitable path planning for the laser beam on the workpiece surface will be developed. This will facilitate a material specific temperature field in the forming zone during the manufacture of industrial relevant, complex shapes. To conserve the high flexibility of metal spinning processes the developed processing strategies will be implemented into software for machine control. Only like that the process can be transferred to industrial use because machine operators can set-up the process as today without the need for laser specific expert knowledge.

S. Kamboj. et.al. [25] analyzed the effects of different types of tool on metal spinning process. It is recorded that the required force is increasing from the beginning and towards the outer end of the sheet. Thus, maximum chance of defects will be occurring at the outer end of the sheet.Shearing takes place in the sheet due to hard material of tail stock support and high rpm of the machine. The wrinkle defects and back flow of sheets are observed by providing feed motion manually.Superior structure is observed by revolution of the machine is 465 rpm and tool feed rate of the machine is (0.04 mm/rev.) which are maintained with the help of coping attachment. The mean of force is minimum at T3 tool at same feed and spinning speed and hence it is concluded that tool T3 (Taper roller wheel) is the best for spinning among the three tool shapes for spinning of cone or frustum of cone.The mean of force minimum at speed 465 rpm and at feed rate 0.04 mm/rev. From the experimental work it is concluded that the optimum condition for spinning of cone or frustum of cone is tool T3, Speed 465 rpm, feed rate 0.04 mm/rev.

I.M. Russo. et.al. [26] studied Haptic metal spinning. Force control in conventional spinning. Force control may provide a new perspective on toolpath design to avoid failure. The way force changes with position along the flange depends on the current shape of the workpiece and on the accumulated work done so far; therefore, designing a force profile to avoid failure may turn out to be more reliable than a positional approach. Future investigations may attempt to design full toolpaths by force control and thus may include design of the radial force Fr in the later stage of the process; hybrid position/force control approaches may also be explored. Wrinkling avoidance and recovery. We have shown that wrinkling is recoverable with an easy-to-design toolpath. Our analysis of the shape evolution data obtained from the sensors is an example of the opportunities offered by haptic metal spinning to reveal relationships between the motion of the roller along the flange, foldback and the likelihood of wrinkling. The operator could feel when wrinkling was about to happen because of the vibrations and the sounds coming from the workpiece. This suggests there may be ways to sense information from the workpiece to correct the toolpath online and avoid wrinkling. Capturing craftsmen skills. Process models of metal spinning are too slow or too imprecise to help designing toolpaths automatically. Instead, spinning craftsmen can react to unexpected variations during a spinning process and avoid failure by performing actions learnt over years of experience. By having craftsmen use the haptic metal spinning set-up presented, their actions may be studied and parameterized so that widely applicable rules to design full toolpaths may be derived.

Q. Xia. et.al.[27] gave a review of Process Advancement of Novel Metal Spinning**.** In this paper, a classification method of metal spinning processes covering a broad range of spun part geometry 34/39 is presented, which not only includes the classification of traditional spinning processes, but also includes the novel spinning processes emerged in the recent years. The traditional spinning processes are classified based on the deformation characteristics of material, the relative position between roller and blank, mandrel or mandrel-free spinning, and the temperature of the blank during spinning. Recently developed novel spinning processes and equipment are reviewed in detail, these include non-axisymmetric spinning, non-circular cross-section spinning, tooth shaped spinning. The classification of the novel spinning processes is proposed based on the relative position between rotational axes, the geometry of cross-section and the variation of wall-thickness of the spun part. The development of these novel processes has allowed the spinning to be used for various new industrial applications. The reviewed novel spinning processes are mainly used to manufacture the parts with complex geometries which have found applications in the automobile industry. The materials used in these novel spinning processes are mainly pure Aluminium, Aluminium alloy and low carbon steel tubes or sheets. Majority of the spun parts manufactured by the novel spinning processes have met the quality requirement of their specific applications. However, for high precision applications, the dimensional accuracy, such as the wall-thickness deviation of the non-circular cross-section parts, need to be further improved. Recent researches of the novel spinning processes are mainly focused on the macro formability and the forming part quality, future prospects should be developing the controlling method of microstructure evolution during spinning and mechanical properties of the spun parts. Furthermore, in order to manufacture spun parts with high dimensional accuracy and good in-service performance, the integrated optimization method of quality and performance of the spinning processes should be developed. Finally, the types of materials used in the novel spinning should be expanded, and the hot spinning process of the difficult-to-deform metal materials should be explored.

CHAPTER 3: PROBLEM DEFINITION AND METHODOLOGY.

3.1. Objective:

To produce a Circular bowl and Conical shape part using Metal Spinning Process, a metal disc is revolved on a specialized lathe, while held against a spinning block or mandrel, with a follower. As the disc rotates, spinning tools or rollers are used to force the disc onto the spinning block or mandrel.

3.2. Description

What is Metal Spinning?[28]

- Metal spinning is an industrial process that is used for processing metals into a spinning form. The process entails rotating or spinning a disc or tube metal at high speed. As the rotation takes place, the metal is converted into a symmetric part.
- Unlike the popular assumption, metal spinning does not involve the removal of the material from the workpiece. Instead, the metal is physically molded into the desired shape with minimal destruction of the material.
- Metal spinning can be performed manually or through a CNC lathe machining process.

3.3. Parts Required[29]

(i) Bed

The bed of the spinning machine is made of cast iron. It supports the head stock, tail stock, tool rest, tool and other accessories used.

(ii) Head Stock

The head stock of a spinning machine differs from that of a machinist's conventional lathe machine. In a spinning machine, the metal blank is not held in the chuck, but is held by friction between a former and a follower.

(iii) Tail Stock

The tail stock is similar to that of conventional lathe tailstock. It has a quick-action locking lever, which allows the tailstock barrel to slide with ease to engage and dis-engage the live center.

(iv) Former or Chuck

The former or chuck is fixed with the lathe spindle and rotates along it. The workpiece or metal blank is bent over the former to take its shape. Formers are usually made of steel cast iron, cast Aluminium, magnesium alloys, or hard wood such as mahogany. For complex shapes, formers are made up of laminated hardwood blocks, whereas for small and simple shapes they are made of a single piece. The materials of the former must have high strength and resistance to wear.

(v) Live Centre

The live Centre is held and rotated freely in a barrel, which supports the metal blank without friction, with the help of a wooden block called follower.

(vi) Adjustable Steady-Rest

An adjustable lathe steady rest is provided which has a number of adjustable steel pins to hold the tool rest.

(vii) Adjustable Tool-Rest

Adjustable tool rests with adjustable fulcrum pins are provided to hold the pressing tool. Tool-rest is fitted over the steady rest of the spinning lathe machine.

(viii) Follower

The follower is a wooden block that fits over the tail-stock centre and applies the pressure to hold the metal blank on the chuck. It is located between the workpiece and the live Centre.

(ix) Barrel Clamp

The barrel clamp is provided at the tail-stock which clamps the barrel at any position in the tailstock spindle.

(x) Spinning Tool

The spinning or forming tools are made from brass, bronze or steel to a variety of radii.

3.4. Parameters[30]

There are 3 main process parameters that are considered for the spinning process.

These process parameters are as follow

1. Workpiece Parameters

2. Tooling Parameters
3. Process Parameters

1. Work piece Parameter

a) Blank Thickness

Blank thickness is nothing but thickness of blank. The process of metal spinning is capable of forming a workpiece with thickness of 0.5 mm to 30mm. To obtain uniform thickness during a spinning it required a high-speed ratio but this will reduce the geometrical accuracy which is applicable for shear spinning. To calculate the thickness of components sine law is used.

$$tf = t0 \text{ X } \sin\alpha$$

By using this formula we calculate the final thickness of component, where

tf = final thickness

t0= Initial thickness

α = inclined angle

For metal spinning low feed rate and large nose radius are recommended for uniform thickness. In metal spinning high offset values tend to reduce wall thickness. Maximum axial and maximum radial forces are as a function of wall thickness. The inclined angle of the mandrel determines the degree of reduction normal to the surface. The greater the angle, the less will be the reduction of wall thickness.

b) Blank Diameter

Blank diameter is a diameter of metal sheet which is used for producing spun components. Different types of blank diameter used in metal spinning according to product requirements. Generally, in metal spinning cylindrical, hemispherical and cone shaped components are produced, and according to this shape and size blank diameter will change. By equating the area of the blank and area of the designed component the required diameter of the blank is calculated.

Surface area of blank = surface area of the designed component

c) Blank material

To produce a component in metal spinning sheet metal is used. Almost all metals are available in the form of sheet, but the following metals are generally used in this process like Aluminium, stainless steel, copper, brass, tin , silver, gold.

2. Tooling Parameters [[31]

a. Roller Diameter

b. Roller Nose Radius

c. Mandrel Diameter

d. Blank Support Unit

a) Roller Diameter

Roller acts as a tool which applies the force on the metal sheet over the mandrel. Rollers are available in different diameters and different thickness. This roller deforms the metal sheet over the mandrel in several no of passes. According to Hayama, low mandrel speed, small roller diameter and low viscosity lubricant give low surface finish. Roller diameter can be calculated by using the following formula.

Dr=0.1D+ (120±60) mm

Where,

Dr=Roller diameter in mm

D= Original diameter of blank in mm = 300mm

Dr = (0.1 D + 120 ± 60) mm

Dr=0.1*300 + (120-60)

Dr = 90mm

b) Roller nose radius

Roller nose radius has a significant effect on dimensional accuracy. Large nose radius results in uniform thickness distribution and low surface roughness. Which is applicable for conventional spinning. In shear spinning the roller diameter and nose radius has a significant effect on the tangential force component and using a large nose radius leads to better surface quality.

Nr =(0.012~0.05)D

By using this formula, we calculate a nose radius where,

Assume D= 300 mm

Nr = Nose radius in mm

D = Blank diameter in mm

Nr= (0.012+0.05)*300

Nr = 18.6mm

c) Mandrel Diameter

Mandrel is a supporting as well as a rotating member in the metal spinning set up. The shape of the final component is the same as that of the designed mandrel. According to the requirement of shape of the final component mandrel is designed. With the help of mandrel, the sheet metal is rotated and this metal sheet is deformed over the mandrel with the help of roller by applying force on it. The mandrel is a solid part and material used for the mandrel is cast iron, mild steel, Aluminium, Magnesium and plastic-coated wood. When it is necessary to produce a part to close tolerances, the mandrels are typically made entirely of steel and cast iron, cored casting 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.

The material used for the mandrels for cone spinning are selected primarily on the basis of the desired mandrel life. The actual mandrel material selection depends on the 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 volume (250 to 750 pieces) 4150 or 52100 steel hardened to approximately 60HRC can be used. The tool steels such as O6, A2, D2 or D4 hardened to 60HRC or slightly higher are more suitable for high volume production. The surface finish of the mandrels should be at least 1.5µm. The mandrel dimensions should be machined so that they are within ±0.025mm of being concentric with each other.

3. Process Parameters[32]

a. Feed Rate
b. Spindle speed
c. Feed Ratio
d. Temperature
e. Lubricant

a) Feed Ratio

Feed ratio is defined as the ratio of roller feed rate to spindle speed. High feed ratio helps to maintain original blank thickness. It also leads to material failures & rough surface finish. Variation of feed ratio has considerable effect on the tool forces, wall thickness, Spinnability, Surface finish & spring back of the metal spinning process. When a higher feed ratio is applied, tool forces will increase. Low feed ratio would result in excessive material flow in the outward direction, which unnecessarily reduces thinness but due to low feed rate better surface finish obtained.

Low Feed ratio is better for the spinning process because good surface finish is obtained and no failure of components takes place. For Aluminium feed ratio is 0.9 mm/rev and for mild steel feed ratio is 1.8 mm/rev.

b) Feed Rate

The roller feed rate, which is one of the important parameters affecting the formability and forming quality. The Distance of the tool advances into or along the workpiece each time is called the feed rate. It is measured in mm/sec or mm/ min. Due to the high feed rate rough surface finish & wrinkling may occur. A decrease in feed rate will improve the surface finish while increase in feed rate will make a workpiece fit to mandrel and the finish of workpiece will become coarser. In order to realize synchronous motion control of mandrel and roller, the number of pulse signals for mandrel rotation, mandrel feed and roller feed are maintained constant for a given time interval. During 1 path spinning the roller move from mandrel slope is set to 2.4 mm/sec.

c) Spindle Speed

The best quality for most components is achieved when spinning at high speed. The effect of mandrel speed on the tool forces is negligible. He points out that the effect of the mandrel speed is negligible, and gives a wide range of feasible mandrel speed. The influence of rotational speed on the variation of axial and radial forces is negligible. For Aluminium material we take Spindle speed 800 to 900 rpm.

$$N = (9500 \sim 320000)/Do$$

Mandrel speed is calculated by using this formula where,

N = mandrel speed in rpm

Do = original blank diameter in mm

N = 270000/300

N = 900 rpm

d) Temperature

The use of elevated metal temperatures is sometimes required during metal spinning to reduce the flow stress and increase the ductility of the component, particularly if the machine capacity is insufficient for cold forming the component or if the alloy ductility is too low. Spinning processes are typically performed cold, but for thick parts and high strength material, heating is sometimes applied to reduce the forming forces. In this method heating of the sheet metal is done by hand held oxy acetylene flame. Sometimes hot air is also used to heat the blank.

e) Lubricant

A lubricant is almost always used during spinning. The fluid used serves as both a lubricant and coolant. A Water based coolant, such as an emulsion of soluble oil in water ,is most commonly used, and in large quantities because of large amount of heat generated .When spinning Aluminium, 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 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. 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 performance 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 pigmented drawing compounds; in the selection of the most suitable lubricant, the ease of removal of the lubricant after forming has to be considered.

3.5. Process[33]

Step 1-Fix the cut circular metal plate on the machine mandrel.

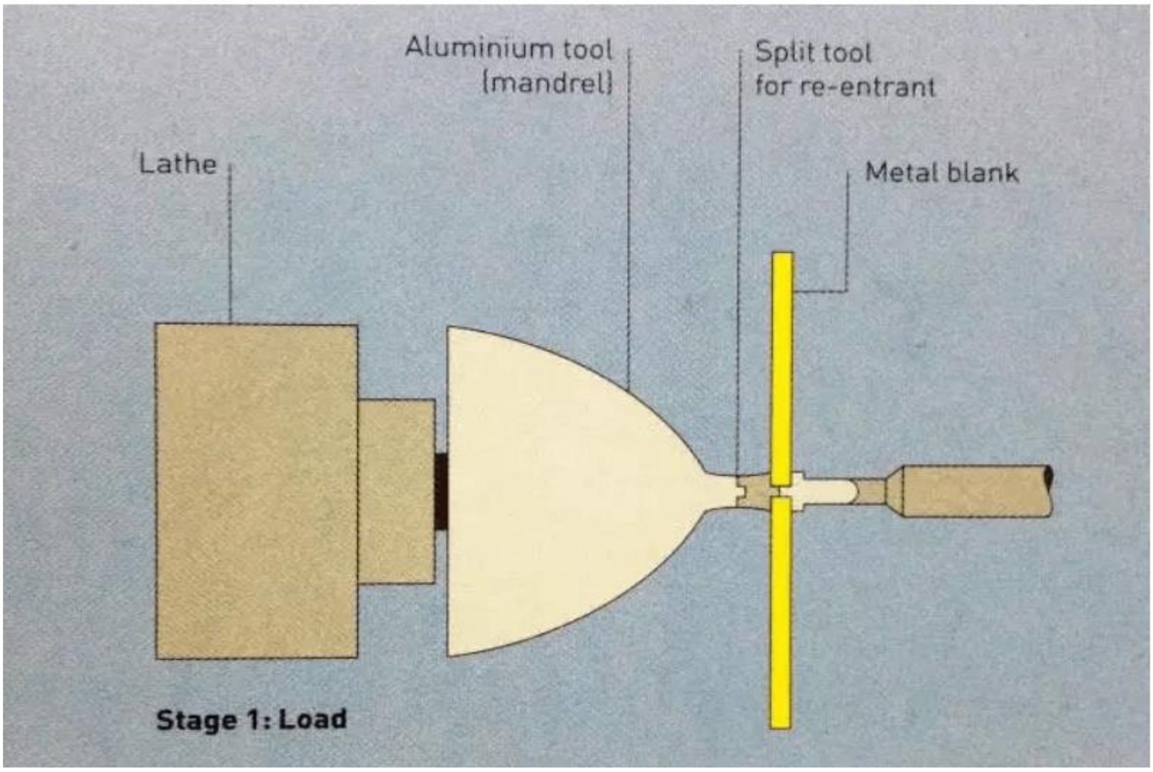

Fig. 3.1 Step 1- Load[34]

Step 2-The mandrel drives the circular metal plate to rotate at high speed, and the tool with the wheel starts to press the metal plate completely fits the inner wall of the mould.

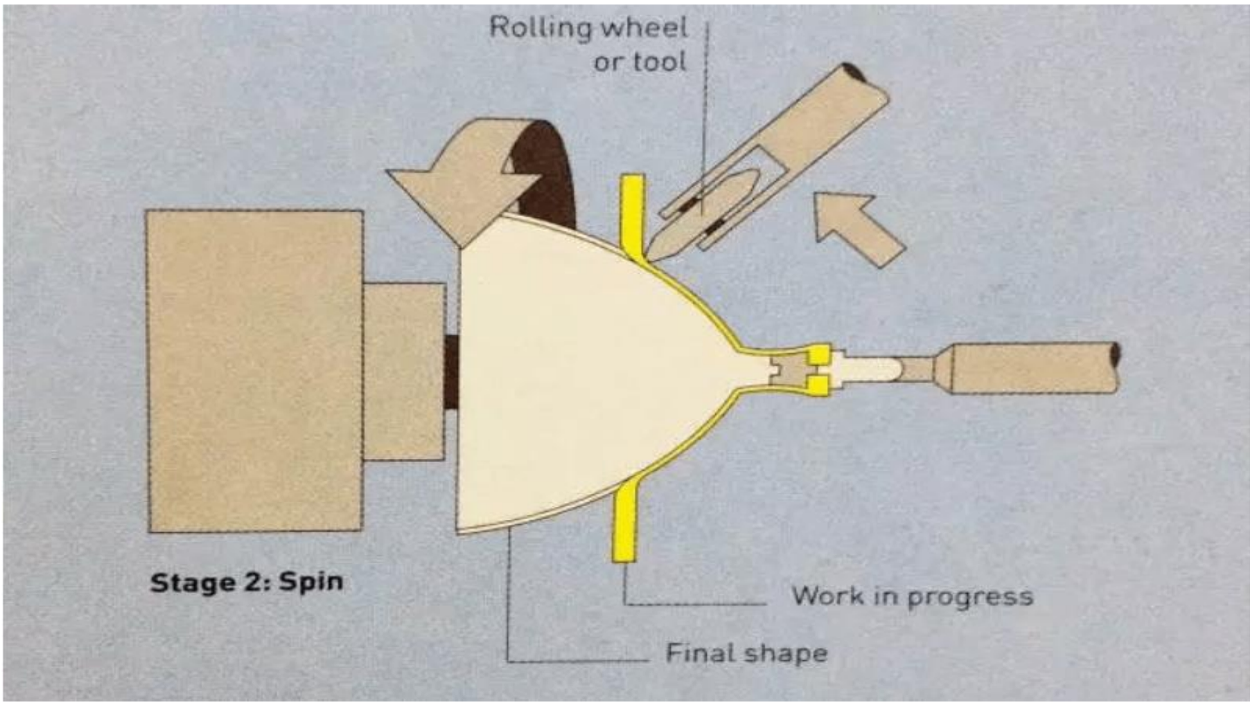

Fig. 3.2 Step 2-Spin[35]

Step 3-After molding is completed, the mandrel is removed and the top and bottom of the part are cut off for demolding.

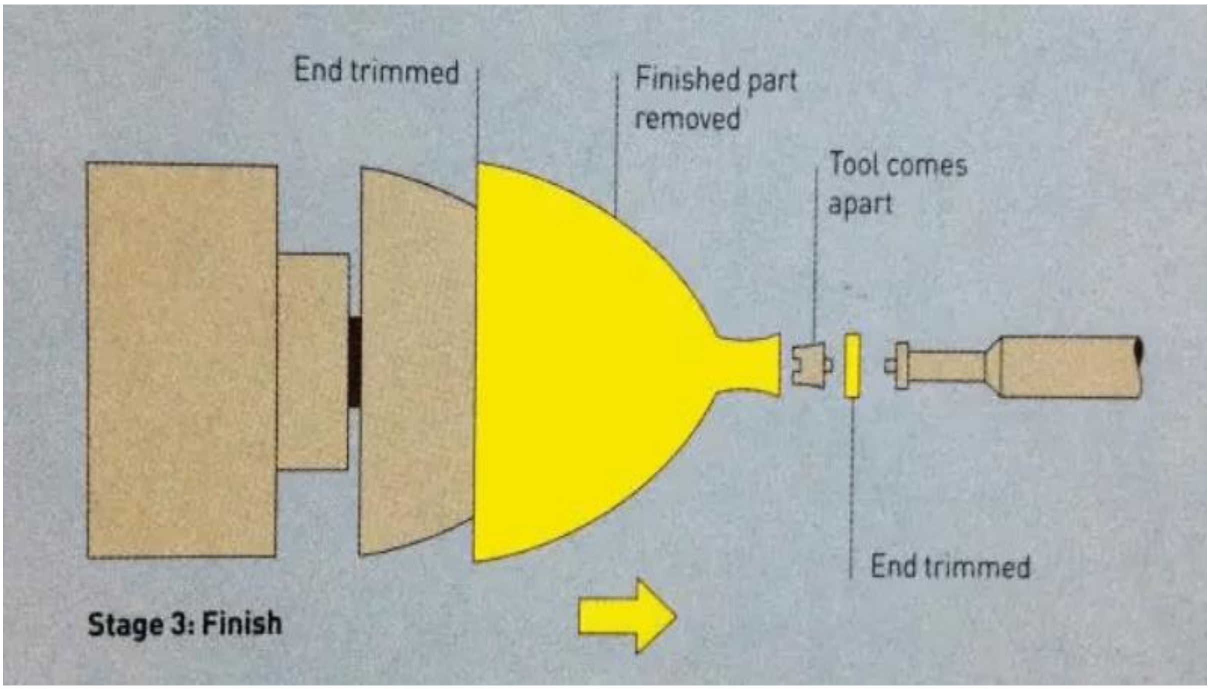

Fig. 3.3 Step 3-Finish[[36]

3.6. Applications:-[37]

The metal spinning process has a wide range of applications. Basically, you can easily identify products of metal spinning by observing their shapes.

Some of the common shapes of metal spinning include: -

- Conical
- Spherical
- Semi-spherical
- Parabolic
- Venturi
- Cylindrical
- Toroidal

In relation to that, there are different types of metals that are used for spinning. They include: -

- Stainless steel
- Copper
- Aluminium
- Carbon steel
- Titanium
- Brass

From the above shapes and lists, we can easily list products such as automotive parts, gas cylinders, satellite dishes, cookware, among others. This list also shows that the applications of metal spinning spread across different industries.

3.7. Limitations of Metal Spinning:[38]

(i) More Time Required: The time required to produce a cup is more in spinning than drawing process.

(ii) More skill Required: The spinning process requires more skill of operator as tool is manually passed against the metal blank.

(iii) Not suitable for large-scale Production: The spinning process is not suitable for large-scale production, as it consumes more time.

(iv) Strength: Although metal spun products are considered strong, in some cases when they are compared to other types of metal processing, they can be referred to as a weaker material.

(v) Snarl: Due to the nature of this process, snarling is more likely to occur when it comes to metal spinning, this means it may leave a small imperfection on the surface of the metal.

(vi) Difficulty with keeping the spinning consistent: When it comes to the metal spinning process, it can be more difficult to keep the spinning condition constant.

(vii) Increases the unevenness and imperfections: This type of process can also increase the unevenness and imperfections due to the speed of the spinning; this can also contribute to the strength of the product.

CHAPTER 4: DESIGN OF METAL SPINNING MACHINE

4.1 Introduction:[39]

Metal spinning is the technique to produce an axis symmetrical part or component over a rotating mandrel with the help of a rigid tool known as roller. The spinning process also enables components to be produced with both improved mechanical properties of almost 2 to 2.5 times their value in the raw material condition as well as with high dimensional accuracies and surface finishes. Such components mostly find application in the aircraft and missile industries which require a high strength to low weight ratio for their component. In addition, it may provide a practical approach of standardized operation for the spinning industry and thus improve the product quality, process repeatability and production efficiency. Metal spinning refers to a group of forming processes that allow production of hollow, axially B group of processes, consists of clamping a sheet metal blank against a mandrel on a spinning lathe, and gradually forming the blank onto the mandrel surface by a roller, either in a single step or series of steps.

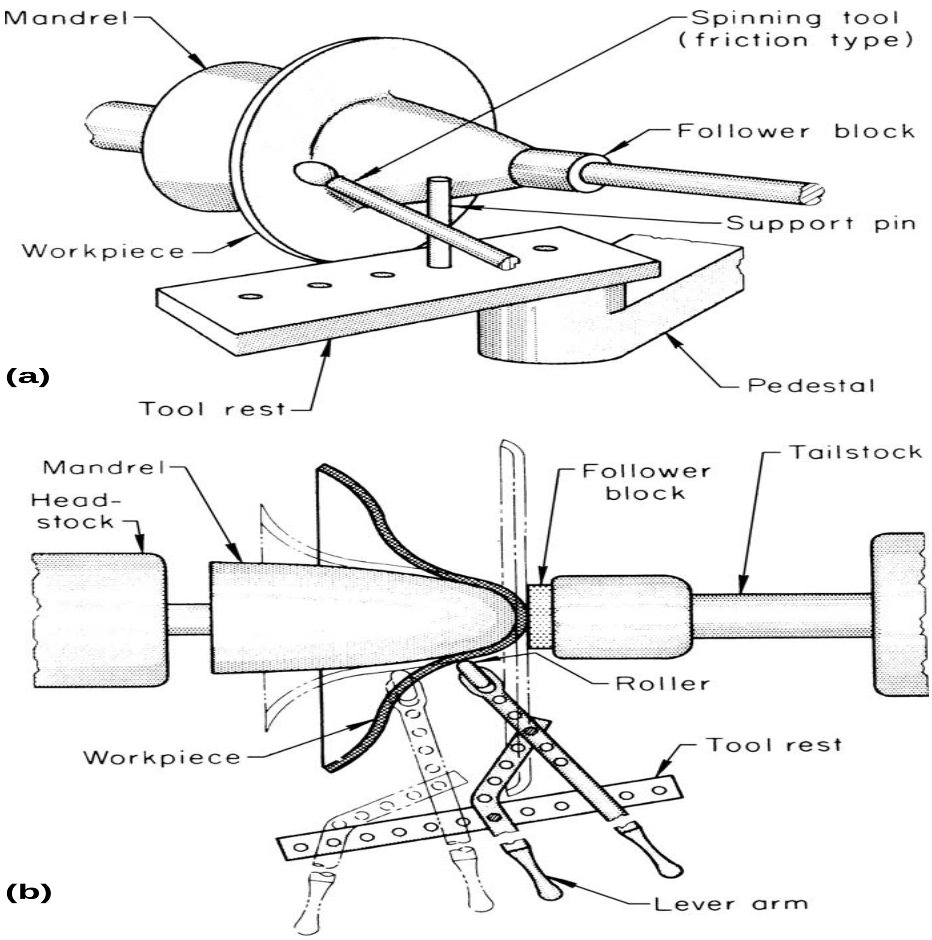

Fig 4.1Metal Spinning Process[40]

4.1.2 Process Parameters:

There are many process parameters like radius of roller nose, diameter of the mandrel, study parameters like feed rate, speed of the spindle and feed ratio. In this experiment, roller nose radius and sheet material as varying input parameters as described in table 4.1 while forming force, surface roughness, strain are studied as output parameters and the number of experiments conducted are mentioned in table 4.2.

Table 4.1 Input parameters[41]

Material	Thickness	Rollers	Roller nose radius
Brass	0.6mm	1	3.5mm
Copper	0.6mm	2	10.5mm

Table 4.2 Practical Setup[42]

Trial	Material	Roller nose radius
1.	Brass	3.5mm
2.	Brass	10.5mm
3.	Copper	3.5mm
4.	Copper	10.5mm

4.1.3 Practical:

Metal Spinning Operation was conducted manually on a lathe machine, on which spin forming setup is done. The tool and mandrel are made of EN10 material, with brass and copper as workpiece materials. As per the requirement of metal shape, the shape of mandrel is opted for providing a wide range of conditions. A metal sheet of maximum diameter 50 mm is chosen and is modeled into a cup with an inner section of a circular surface of diameter 30 mm. The shape is very close to that of investigation of working forces in conventional metal spinning. The forming force is found using the lathe tool dynamometer and surface roughness values are calculated using surface roughness tester.

Table 4.3 Output parameters[43]

Trials	Forming force (kgf)	Surface Roughness (μm)	Strain
1.	50.98	9.3852	0.37
2.	81.57	6.5305	0.41
3.	66.28	4.7213	0.39
4.	91.77	8.8454	0.44

Table 4.4 FEA Result of Stress[44]

Trials	Stress
1.	1.562*100000 N/mm²
2.	1.986*100000 N/mm²
3.	1.687*100000 N/mm²
4.	2.931*100000 N/mm²

Table 4.5 Design of Metal Spinning Parameters:[45]

Angle A	Initial Blank Thickness (t_o)	Final Component Thickness (t_f)	Percentage of Reduction $\frac{(to - tf)}{to} * 100$
12	0.5	0.103	79%
	1	0.207	79%
	2	0.413	79%
15	0.5	0.129	74%
	1	0.255	74%
	2	0.517	74%

45	0.5	0.353	29%
	1	0.707	29%
	2	1.414	29%
60	0.5	0.433	13%
	1	0.866	13%
	2	1.732	13%

a) Blank Thickness:

To calculate max. % of thickness reduction = $\frac{(to - tf)}{to} * 100$

The Chart below shows the Percentage of Reduction in Thickness of Component according to variation of half-apex angle of Mandrel.

b) Blank Diameter:

Blank diameter is a diameter of metal sheet which is used for producing spun components. Different size of blank diameter used in metal spinning according to product requirement. Generally, in metal spinning cylindrical, hemispherical and cone shaped components are produced, and according to this shape and size blank diameter will change.

D = Diameter of blank

R = Large Radius of cone

r = Small Radius of cone

S = Slant height of cone

Surface area of blank = surface area of cone

$$\pi/4 \times (D)2 = \pi \times (R + r) \times S$$

$$D = 2 \sqrt{} (R + r) \times S$$

c) Blank Material:

To produce a component in spinning sheet metal is used. Almost all metals are available in the form of sheet, but the following metals are generally used in this process like Aluminium, stainless steel, copper, brass, tin, silver, gold.

Design of Workpiece Parameters:

1. Aluminium -

Aluminium is a very ductile material among all the types of material and there are different types of grade present in Aluminium. It is elastic in nature and does not require any heat treatment.

Following are grades of Aluminium,

a. 1100- H14 - This type of Aluminium is pure in nature. It is a soft metal among all types of Aluminium grade. The percentage of elongation is 60% which is greater than all types of Aluminium grade. It has 99% Aluminium and 1% alloy. It is commonly used in chemical processing equipment, light reflectors, and jewelry.

b. 3003- H14 - This type of Aluminium is harder than 1100-H14 because it contains 98% Al, 0.12% cu and 1.2 % Mn. The percentage of elongation is 30%. It is often used in stamping and drawn parts, mail boxes, cabinets, tanks, and fan blades

c. 5052- H32 - This type of Aluminium is harder than 3003- H14. It is hard to deform, it contains 97% Al, 2.5% mg, 0.25% Cr. The percentage of elongation is 25%. Common applications include electronic chassis, tanks, and pressure vessels

d. 6061- T6 - This type of Aluminium is harder than all types of Aluminium. The percentage of elongation is 25%. Aluminium is most widely used in metal spinning because it has the ability to easily deform. It is used in modern aircraft structures

2. Stainless steel –

It is also in elastic nature and stretches before tearing. Percentage elongation is 50-68% but disadvantage of stainless steel is it requires more force to deform the metal.

3. Copper -

The main property of copper is it is good in formability and has double its tensile strength when work hardened. It is hardened before the part is finished then the part must be annealed to prevent cracking. It contains 99% Cu. The percentage of elongation of copper is about 60%.

4. Brass -

Brass is a copper zinc alloy and has the same properties as Cu. It requires more force to deform and it hardens less. It contains 65% Cu and 35% Zn. the percentage of elongation of brass is 64%. But we select Aluminium 1100 grade material for blank due to its good ductility and high percentage of elongation.

Temper Designation System:

Aluminium city utilizes a temper designation system similar to the ISO 2107 "alternative a temper designation system "which is widely recognized internationally and closely approximates that the Aluminium association. The system defines the sequence of basic treatments used to achieve the various tempers. The temper designation follows the four digits Aluminium alloy designation, the two being separated by a hyphen. Basic temper designation consists of letters whereas subdivisions of these basic tempers are indicated by one or more digits following the letters.

a) Basic Temper Designation System:

i. O Annealed -Applies to wrought products which are annealed to obtain the lowest strength condition.

ii. H Strain-hardened - (wrought product only). Applies to products subjected to the application of cold work after annealing (or hot forming) or to a combination of cold work and partial annealing or stabilizing in order to secure the specified mechanical properties. The H is always followed by two digits.

iii. T Thermally treated -to produce stable tempers other than O or H. Applies to products which are thermally treated, with or without supplementary strain-hardening, to produce stable tempers. T is always followed by one digit.

b) Subdivisions of H Temper: Strain-hardened

i. H1x Strain-hardened only. Applies to products which are strain hardened to obtain the desired strength without supplementary thermal treatment. The number following the designation indicates the degree of strain -hardening.

ii. H3x Strain-hardened and stabilized. Applies to products which are strain-hardened and whose mechanical properties are stabilized by a low temperature thermal treatment which result in slightly lower tensile strength and improved ductility. The number following the designation indicates the degree of strain -hardening remaining after the stoving process.

c) Subdivisions of T temper: Thermally treated

i. T3 Solution heat- treated, cold worked and naturally aged to a substantially stable condition. Applies to products which are cold worked by a control amount to improve their strength after solution heat-treatment, or in which the effect of cold work in flattening or straightening is recognized in mechanical property limits.

ii. T6 Solution heat-treated and then artificially aged. Applies to products which are not worked after solution heat-treatment, or in which the effect of cold work in flattening or straightening may not be recognized in mechanical property limits.

Design of Tooling Parameters:[46]

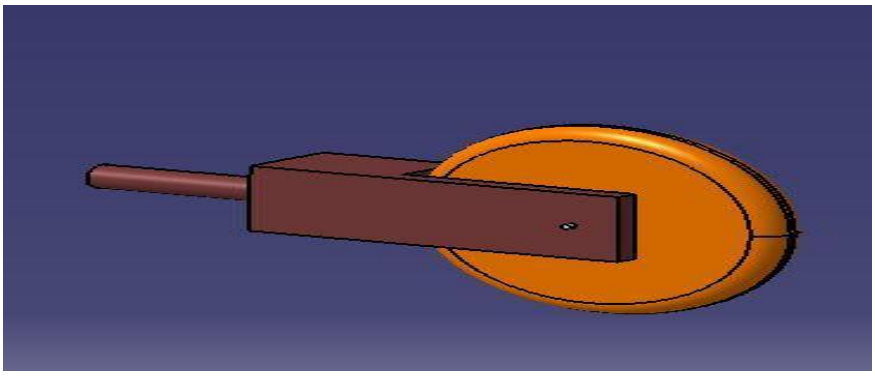

Fig 4.2 Spinning Tool

a) **Roller Diameter:**

Roller acts as a tool which applies the force on the metal sheet over the mandrel. Rollers are available in different diameters and different thickness. This roller deforms the metal sheet over the mandrel in several no of passes. According to Hayama, low mandrel speed, small roller diameter and low viscosity lubricant give low surface finish. Roller diameter can be calculated by using the following formula

$$D_r = 0.1D + (D \pm R) \text{ mm}$$

Where, R = Large Radius of cone

D_r =Roller diameter in mm

D = Original diameter of blank in mm

Check condition, If roller diameter always less than diameter of component

Then, Dr = [0.1 (Dr) + (D - R)]

We select a Roller diameter Dr in mm because roller diameter is always less than the blank diameter.

b) **Roller Nose Radius:**

Roller nose radius has a significant effect on dimensional accuracy. Large nose radius results in uniform thickness distribution and low surface roughness. Which is applicable for conventional spinning. In shear spinning the roller diameter and nose radius has a significant effect on the tangential force component and using a large nose radius leads to better surface quality.

$$Nr = (0.012 \sim 0.05)\, D$$

By using this formula, we calculate a nose radius where,

N_r = Nose radius in mm

D = Blank diameter in mm

Nr= (0.012+0.05)*300

Nr = 18.6mm

c) Force Calculations:[47]

Most of the process of spinning is conducted by trial-and-error basis. Force between the work piece and Roller generated during shear forming can be resolved into three mutually perpendicular components, namely the axial (F_a), Radial (F_r) & Tangential (F_t). It has been experimentally observed that tangential force is smaller than axial & radial forces. Although most of the power supplied by the motors driving the chuck is translated through the tangential component.

Feed ratio, mandrel speed, sheet thickness, roller diameter, roller nose radius affects the tool forces. Mandrel rotational speed has an optimum value. Slater and chan et al both report that there is a mandrel speed at which tangential force is negligible. For sheet thickness there is a linear directly proportional relationship between thickness and all three forces. The influence of roller diameter and roller nose radius on tool force was examined by avitzur and yang he reported that the tangential force decreases with increase in both parameters, whereas axial and radial forces increase.

The axial forces are the highest among three force components, while the tangential force is the lowest; ratios between maximum radial forces to maximum tangential forces of all the four roller path profiles remain unchanged as 5:1. However, the ratios of maximum axial force to maximum tangential force vary between 13:1 for the convex roller path and 17:1 for the linear roller path. The concave path produces the highest radial, axial and tangential forces among these four roller path profiles considered. The lowest axial and tangential forces are observed in the FE models which use the convex roller path. Therefore, it is clear that a convex roller path generally produces the lowest tool forces.

Where,

F_a = Axial force

F_r = Radial forces

F_t = Tangential force

The Tangential forces are as follows

$F_t = (t_o - C_s) \sin\alpha\, f \int \sigma d\varepsilon$

We know that,

t_0 = Initial Blank thickness = 2 mm

C_s= Over-roll Depth

α = Half-cone angle = 150

f = Roller feed = 1000 mm/ min

σ = Effective Stress

$d\varepsilon$= Infinitesimal effective strain

According to Hooke's law,

σ α ϵ

σ = E × ϵ

Where,

σ = Stress

ϵ = Strain

E = Young modulus of elasticity

For Aluminium,

σ =110 MPa=110 N/mm^2

E= 69 × 10^3 N/mm^2

$\epsilon = \frac{\sigma}{E} = \frac{110}{69 \times 10^3}$

$\epsilon = 1.594 \times 10^{-3}$

Assume,

C_s = Over-roll Dept =0.1 mm

$F_t = (t_0 - C_s) \sin\alpha\, f \int \sigma\delta\varepsilon$

$F_t = (2 - 0.1) \times \sin 15 \times 1000 \times \int E \times \sigma d\varepsilon$

$F_t = (2 - 0.1) \times \sin 15 \times 1000 \times E \times (\frac{\epsilon^2}{2})$

$F_t = (2-0.1) \times \sin 15 \times 1000 \times 69 \times 10^3 \times \frac{(1.594 \times 10^{-3})^2}{2}$

$F_t = (2 - 0.1) \times \sin 15 \times 1000 \times 69 \times 10^3 \times 1.2704 \times 10^{-6}$

F_t = 43.106 N = 4.394 Kg

The ratios of maximum axial force to maximum tangential force vary between 17:1

$\frac{F_a}{F_t} = \frac{17}{1}$

But tangential force is F_t= 43.106 N then Calculate Axial force F_a

$F_a = 17 \times F_t$

$F_a = 17 \times 43.106$

F_a = 732.802 N = 73.280 Kg

The ratios of maximum radial force to maximum tangential force vary between 5:1

$$\frac{F_r}{F_t} = \frac{5}{1}$$

But tangential force is F_t = 43.106 N then Calculate Radial force F_r

$F_r = 5 \times F_t$

$F_r = 5 \times 43.106$

F_r = 215.53 N = 21.553 Kg

d) Selection of Bearing for Roller:

A Bearing is a mechanical element that permits relative motion between two parts, Such as the Shaft and the housing, with minimum friction. The functions of bearing are as follows;

a. The bearing ensures free rotation of the shaft or the axle with minimum friction.

b. The bearing Supports the Shaft or the axle and holds it in the correct position.

c. The bearing takes up the forces that act on the Shaft or the axle.

Bearings are classified in different ways. Depending upon the direction of force that acts on them, bearings are classified into two categories- Radial and Thrust bearings. A radial bearing supports the load, which is perpendicular to the axis of the shaft. A thrust bearing supports the load, which acts along the axis of the shaft. The most important criterion to classify the bearing is the type of friction between the shaft and bearing surface. Depending upon the type of friction, bearings are classified into two main groups-sliding contact bearings and rolling contact bearing. sliding contact bearings are also known as plain bearings, journal bearings or sleeve bearings. Rolling contact bearings are also called antifriction bearing or simply ball bearings. Rolling elements, such as balls or rollers, are introduced between the surfaces that are in relative motion. In this type of bearing, sliding friction is replaced by rolling friction.

Deep Groove Ball bearing

The most frequently used bearing is deep groove ball bearing. It is found in almost all kinds of products in general mechanical engineering. In this type of bearing, the radius of the ball is slightly less than the radius of curvature of the groove in the races. Kinematically this gives a point of contact between the ball and the races. Therefore, the balls and the races may roll freely without any sliding. Deep groove ball bearing has following advantages:

1. Due to the relatively large size of the balls, deep groove ball bearing has high load carrying capacity.

2. Deep groove ball bearing takes load in radial as well as axial direction.

3. Due to point contact between the balls and races, frictional loss and the resultant Temperature rise is less in this bearing. The maximum permissible speed of the shaft depends upon the temperature rise of the bearing. Therefore, deep groove ball bearing gives excellent performance especially in high-speed application.

4. Deep groove ball bearing generates less noise due to point contact.

5. Deep groove ball bearings are available with bore diameter from a few million meters to 400 millimeters.

e) Mandrel Design:

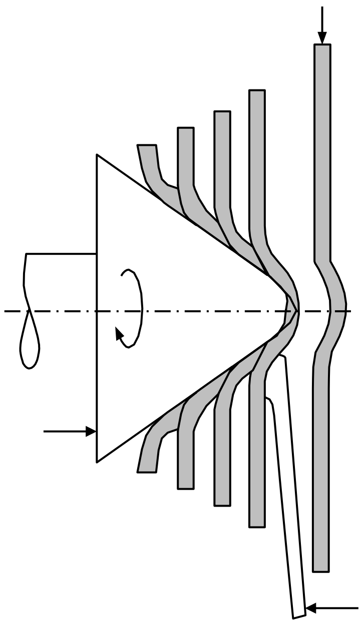

Fig 4.3 Mandrel[48]

Mandrel is a supporting as well as a rotating member in the metal spinning set up. The shape of the final component is the same as that of the designed mandrel. According to the requirement of shape of the final component mandrel is designed. With the help of mandrel, the sheet metal is rotated and this metal sheet is deformed over the mandrel with the help of roller by applying force on it. The mandrel is a solid part and material used for the mandrel is cast iron, mild steel, Aluminium, Magnesium and plastic-coated wood. When it is necessary to produce a part to close tolerances, the mandrels are typically made entirely of steel and cast iron, cored casting 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 dynamically balance.

The materials used for the mandrels for cone spinning are selected primarily on the basis of the desired mandrel life. The actual mandrel material selection depends on the 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 volume (250 to 750 pieces) 4150 or 52100 steel hardened to approximately 60HRC can be used. The tool steels such as O6, A2, D2 or D4 hardened to 60HRC or slightly higher are more suitable for high volume production. The surface finish of the mandrels should be at least 1.5µm. The mandrel dimensions should be machined so that they are within ±0.025mm of being concentric with each other.

i. Material selection

The actual mandrel material selection depends on the design, part material and desired life. According to this criterion we select a Mild Steel because,

- Mild steel contains less than 0.3% carbon
- Desired life of mandrel is high
- Used for high production volume
- Due to low carbon content, they are unresponsive to heat treatment
- They can be machined and welded easily

ii. Specification of mandrel

As we want to produce a cone shaped component having range 100 to 120 mm diameter according to this requirement, we design the mandrel having large diameter=120mm Small diameter=60mm Slant height=120mm

iii. Shaft for mandrel: - shaft is a supporting part of a mandrel which holds in the chuck of the lathe machine. The material used for mandrel is mild steel due to properties as mentioned above.

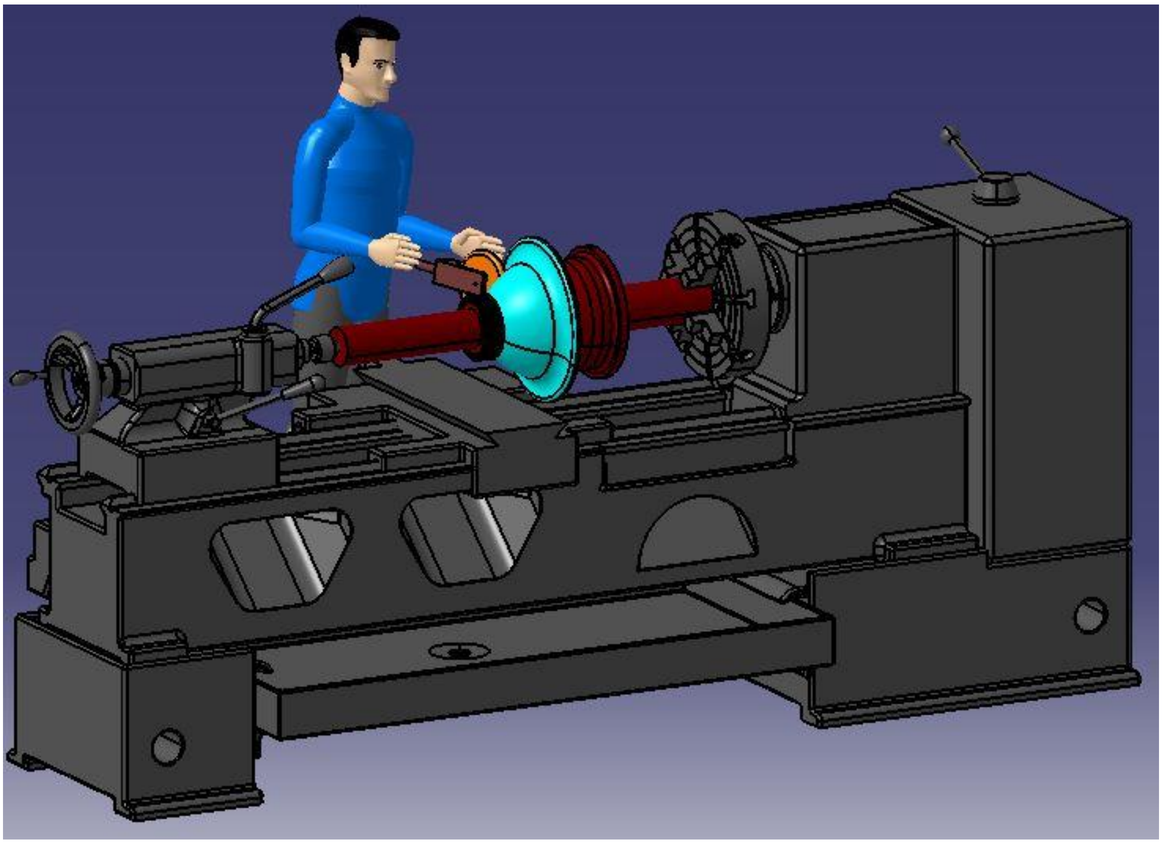

Fig 4.4 Metal Spinning Operation on Lathe Machine.

The beginning of the spinning process is often the most critical, and with the help of a spinning tool, its important the center of the disc is fixated around the mandrel. In doing so, the next set of strokes of the spinning tool can accurately smooth out any warps and ensure the disc remains even. The spinner will use a ‘sweeping’ / radial motion to form the disc over the mandrel. They do this by holding the tool under their arm, and using the force from their shoulder, rib cage and lowered hip, as well as flexed knees and feet firmly flat on the ground. The tool will rest against the pin on the T-Rest, and the tip of the tool will be positioned to the right of the disc.As the body position of the operator stretches upwards, the tip of the tool drops in a small arc from the follow block to the edge of the disc, just like a sweeping motion. The force of the ‘sweeping’ arc of the tool is in one lateral movement towards the headstock. With a combination of moving the upper body towards the right, and the unequal flexing of the knees, the spinner will exert enough force to form the disc over the mandrel. It will require multiple passes to full form the metal disc over the mandrel.

- The metal spinning parameter is directly affected by the workpiece surface finish, tool life, workpiece failure, wrinkling failure. Using this design parameters, we have to reduce the defect & failure occurs in metal spinning operation performed on general lathe
- It has been observed that the formability of the cylindrical cup is maximum when the angle between the tool axis and mandrel axis is 45°.
- The cup depth can be increased from 25 mm to 40 mm using spring loaded tools.
- The metal spinning is simple in conducting the process.
- Metal Spinning Operation results were compared to the results of a simulation that have been performed in Ansys software which show a good tendency on loading.
- Calculations obtained from the conventional spinning have fewer strains than the strains involved in shear forming. Thus, the works carried out to indicate the deformation with the help of dynamic explicit finite element method which is available informing the process.
- This demonstrates that the results obtained in processing parameters have resulted in the maximum error to be not more than ±15%.

Result:

The results of the experiment carried out with different forces applied by nose radius are simulated analytically and are studied as well. The maximum spin forming forces play a vital role in the design of a working machine.

In the analytical study done above, four cases with the different sheet material, roller nose radius were used.

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