Metal Forming By Sheet Metal Spinning Enhancement of Mechanical Properties and Parameter of Metal Spinning

[1]Mahesh shinde, [2]Suresh Jadhav, [3]Kailas Gurav

[1]PG Scholar, [2]Assistant Professor [3]M.E Design
[1,2]Department of Mechanical Engineering, VeermataJijabai Technological Institute,Mumbai, Maharashtra, India-400019
[1]mshinde868@gmail.com, [2]jadhavsuresh1975@gmail.com , [3]kailas_gurav2000@yahoo.co.in

***Abstract* - Sheet metal spinning is one of the metal forming processes, where a flat metal blank is rotated at a high speed and formed into an axisymmetric part by a roller which gradually forces the blank onto a mandrel, bearing the final shape of the spun part. The result of the process depends on the parameter and their interdependence. The parameter in the metal spinning are workpiece parameter, tooling parameter and process parameter, with the help of these three parameter improve the mechanical property andquality of product. The spinning process also enables components to be produced with both improve 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 air craft and missile industries which require a high strength to low weight ratio for their component.**

***Keywords* - Type of Metal Spinning, Spinning Process, Workpiece Parameter, Tooling Parameter, Process Parameter**.

I. Introduction

Metal spinning is the technique to produce axisymmetrical part or component over rotating mandrel with the help of rigid tool known as roller. The product of metal spinning includes:

- 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 cups
- cylinders and drums
- Funnels and horns
- Domes, hemispheres, and shells
- Rings, spun tubing, and seamless shapes
- Vent, venturis, and fan wheel

These components are used for domestic purpose, aerospace application, automobile application etc. Over the last few decades, sheet metal spinning has developed significantly and spun products have been widely used in various industries. Although the spinning process has already been known for centuries, the process design still highly relies on experienced spinners using Trial-and-error. Challenges remain to achieve high product dimensional accuracy and Prevent material failures. This method has been developed to reduce the material deformation and wrinkling failure of the spinning process. By using these techniques in the process design, the time and materials wasted by using the trial-and-error could be decreased significantly. In addition, it may provide a practical approach of standardised operation for the spinning industry and thus improve the product quality, process repeatability and production efficiency.

Fig.1 Spun Components

There are two type of sheet metal spinning

1. Conventional spinning

2. Shear forming

In Conventional method a blank is formed into the desired shape by multiple roller passes. In conventional spinning, the roller tool pushes against the blank until it conforms to the contour of the mandrel .The resulting spun part will have a diameter smaller than the original blank diameter but the original blank thickness will remain same as shown in Figure (a) .

In shear spinning the roller not only bends the blank against the mandrel, it also applies a downward force while it moves, stretching the material over the mandrel. In this method roller deform the blank into a single passes. By doing so the outer diameter of the spun part will remain equal to the original blank diameter, but the thickness of the part will be thinner as shown in Figure (b).

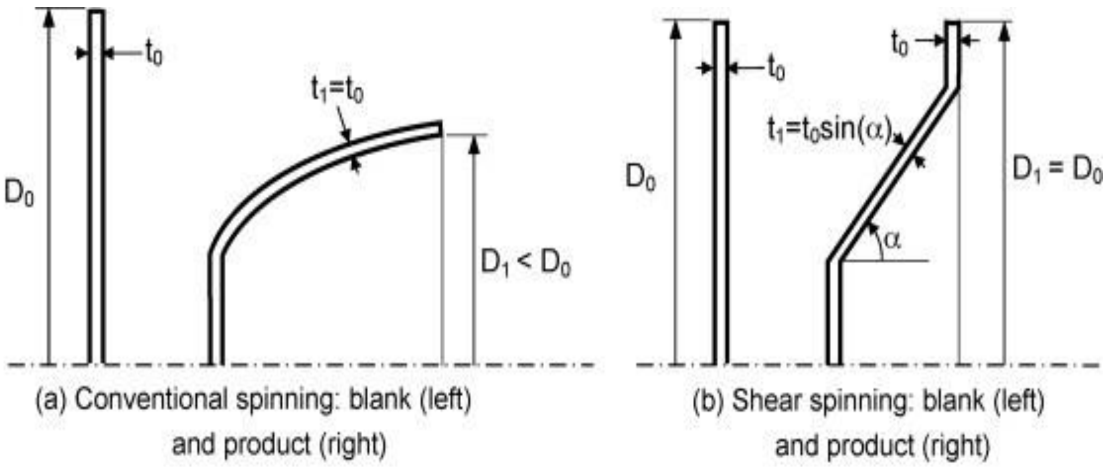

Fig 2 type of sheet metal spinning

II. PROCESS OF METAL SPINNING

Sheet metal spinning is one of the metal forming processes, where a flat metal blank is formed into an axisymmetric part by a roller which gradually forces the blank onto a mandrel& produce the final shape of the spun part. During the spinning process, the blank is clamped between the mandrel and back plate; these three components rotate synchronously at a specified spindle speed. Materials used in the spinning process include non-alloyed carbon steels, heat-resistant and stainless steels, non-ferrous heavy metals and light alloys. The process is capable of forming a workpiece with a thickness of 0.5 *mm* to 30 *mm* and diameter of 10 mm - 5 m. Due to its incremental forming feature, metal spinning has some unique advantages over other sheet metal forming processes. These include process flexibility,non-dedicated tooling, low forming load, good surface finish and improved mechanicalproperties of the spun part. Hence, the sheet metal spinning process has been frequently used to produce components for the automotive, aerospace, medical, construction and defence industries.[1]

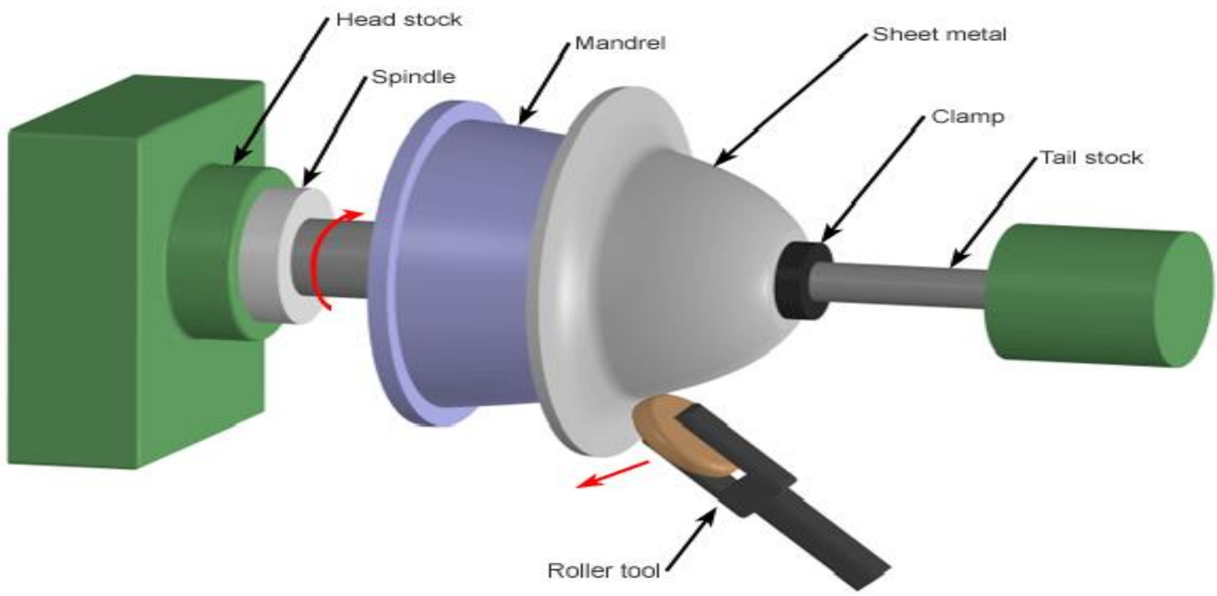

Fig 3

Spinning is the process used for making cup shaped ,conical , Hemispherical articles which are axisymmetrical. Spinning belong to the tension and compression forming processes since tangential compressive and radial tensile stresses are generated in the deformation zone.

III. PARAMETER FOR METAL SPINNINNG PROCESS

There are three main Design parameter are consider for spinning process. These parameter are as follow

3.1 Workpiece Parameters

I. Blank Thickness
II. Blank Diameter
III. Blank Material

3.2 Tooling Parameters

I. Roller Diameter
II. Roller Nose Radius
III. Mandrel Diameter

3.3 Process Parameters

I. Feed Rate
II. Spindle speed
III. Feed Ratio
IV. Temperature
V. Lubricant

3.1 Workpiece Parameters

I) Blank Thickness

Blank thickness is nothing but thickness of blank .The process of metal spinning is capable of forming workpiece with thickness of 0.5 mm to 30mm. To obtain uniform thickness during a spinning it required high speed ratio but this will reduce the geometrical accuracy which applicable for shear spinning. To calculate the thickness of component sine law is used. [2]

$$t_f = t_0 \times \sin\alpha$$

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

t_f = final thickness
t_0= 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 value tend to reduce wall thickness. Maximum axial and maximum radial forces are as a function of wall thickness. The inclined angle of the mandrel determine the degree of reduction normal to the surface .The greater the angle, the lesser will be the reduction of wall thickness.[2]

To calculate max. % of thickness reduction

$$= \frac{(to - tf)}{to} \times 100$$

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

Table 1 Max % of thickness reduction of blank

Angle A	Initial Blank Thickness (t_0)	Final Component Thickness (t_f)	Percentage of Reduction $\frac{to - tf}{to} \times 100$
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 %

II) Blank Diameter

Blank diameter is a diameter of metal sheet which is used for producing spun component. Different size of blank diameter used in metal spinning according to product requirement. Generally in metal spinning cylindrical, hemispherical and cone shaped component 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 component

III) Blank material

To produce a component in metal spinning sheet metal is used . Almost all metal are available in the form of sheet, but following metal are generally used in this process like aluminium, stainless steel ,copper , brass, tin , silver, gold.[5]

A) Aluminium :-

1. Aluminium is very ductile material among all the type of material and there are different type of grade present in aluminium.
2. It is elastic in nature and does not required any heat treatment .
3. Low Specific Gravity.
4. Corrosion Resistance.
5. Ease of Fabrication.
6. High thermal conductivity

Following are the grade of aluminium ,

a) 1100- H14 :-

i. This type of aluminium is pure in nature.
ii. It is soft metal among all type of aluminium grade.
iii. The percentage of elongation is 60% which is greater than all type of aluminium grade.
iv. It has 99% aluminium and 1% alloy.

b) 3003- H14:-

i. This type of aluminium harder than 1100-H14 because it contain 98% Al, 0.12% cu and 1.2 % Mn.
ii. The percentage of elongation is 30%

c) 5052- H32 :-

i. This type of aluminium harder than 3003- H14.
ii. It is hard to deform, it contain 97% Al, 2.5% mg , 0.25% Cr.
iii. The percentage of elongation is 25%.

d) 6061- T6 :-

i. This type of aluminium harder than all type of all type of Aluminium.
ii. The percentage of elongation is 25%.

Aluminium are most widely used in metal spinning because it has ability to easily deform.

B) Stainless steel :-

1. It is also in elastic nature and stretch before tearing .
2. The percentage elongation is 50-68% but disadvantage of stainless steel is it require more force to deform the metal.
3. Stainless steel have higher strength, hardness and toughness.
4. High corrosion resistance.
5. Stainless steel retain their strength and hardness at elevated temperature.

C) Copper:-

1. The main property of copper is good in formability.
2. Copper possesses excellent thermal and electric conductivity.
3. It can be easily cast, machined and brazed.
4. It has good corrosion resistance
5. Have double its tensile strength when work hardened.
6. It is hardened before the part is finished then the part must required to annealed to prevent cracking. it contain 99% Cu.
7. The percentage of elongation of copper is about 60%.

D) Brass:-

1. Brass is a copper zinc alloy and has a same properties to Cu.
2. It contain 65% Cu and 35% Zn.
3. Brass has excellent corrosion resistance
4. Brass has better machinability.
5. Brass has good thermal conductivity.
6. The strength and ductility of brass depends upon the zinc content.
7. The tensile strength of brass is higher than that of copper.
8. Brass is cheaper than copper.

It require the more force to deform and it works hardens less.

3.2 Tolling Parameter:-

I) Roller Diameter : -

Roller acts as a tool which applies the force on the metal sheet over the mandrel. Rollers are available in different diameter 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.[4]

$$D_r = 0.1D + (120 \pm 60)\ \text{mm}$$

Where,

D_r=Roller diameter in mm
D= Original diameter of blank in mm

Dr = (0.1 D + 120 ± 60) mm

II) Roller nose radius:-

Roller nose radius has a significant effect on a dimensional accuracy. Large the nose radius result 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 tangential force component and using a large nose radius lead to better surface quality.[4]

Nr = (0.012 ~0.05) D

By using this formula we calculate a nose radius where,
Nr = Nose radius in mm
D = Blank diameter in mm

III) Mandrel Diameter:-

Mandrel is a supporting as well as a rotating member in the metal spinning set up. The shape of final component is same as that of the designed mandrel. According to requirement of shape of 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 mandrel is cast iron, mild steel, Aluminium, Magnesium and plastic coated wood. When it is necessary to produce a parts 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 and the mandrels should also 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.[2]

3.3 Process parameter

I) Feed Ratio :-

Feed ratio is defined as it is ratio of roller feed rate to spindle speed. High feed ratio help 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, Spinability, Surface finish & spring back of the metal spinning process. When higher feed ratio is applied, tool forces will increases. Low feed ratio would result in excessive material flow in the outward direction, which unnecessarily reduces thins the blank but due to low feed rate better surface finish obtained.[6]

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

II) Feed Rate

The roller feed rate, which is one of the important parameter affecting the formability and forming quality. It is a Distance of the tool advances into or along the work piece each time is called as feed rate. It is measure in mm/sec or mm/ min. Due to the high feed rate rough surface finish & wrinkling may be occur. A decrease in feed rate will improve the surface finish while increase in feed rate will make a work piece fit to mandrel and the finish of work piece will become coarser. In order to realize synchronous motion control of mandrel and roller, the number of pulse signal 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.

III) Spindle Speed

The best quality for most components is achieved when spinning at high speed. According to hayama the effect of mandrel speed on to the tool forces is negligible. He point 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.[4]

$$N=\frac{(9500\sim320000)}{Do}$$

Mandrel speed is calculated by using this formula where,
N= mandrel speed in rpm
$D_{0=}$ original blank diameter in mm

IV) 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 process are typically performed cold, but for thick part and high strength material, heating is sometime applied to reduce the forming forces. In this method heating of the sheet metal is done by hand held oxyacetylene flame. Sometime hot air is also used to heat the blank.[2]

V) 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.[2]

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 preform 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.

IV. CONCLUSION

This article has described two type of metal spinning, metal spinning process and three important parameter like workpiece parameter, Tooling parameter, process parameter with the help of these three parameter we design metal spinning process. The benefits of metal spinning are

1. The tooling cost would be reduced for large components in spinning process
2. High accuracy obtained in 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 was increased by 2 to 2.5 times in spinning process

References:-

[1] Dr. R. Uday Kumar , “A study on deep drawing and spinning process in sheet metal forming,” International journal of Application, 2012, pp. 170-175.
[2] B.P.Bewlay, “Spinning,” ASM Handbook, volume 14B, pp.367-374
[3] Ichiro Shimizu, “Asymmetric forming of aluminium sheet by synchronous spinning,” journal of material processing technology 210(2010), pp.585-592
[4] J.M Allwood, “A review of mechanics of metal spinning,” Journal of Material Processing Technology 210(2010), pp.3-23
[5] AD, “metal spinning (Halifax),” material suitable for metal spinning, pp.1-7
[6] C.C.Wong, T.A.Dean, " A review of spinning ,shear forming and flow forming process,"International Journal of Machine Tool & Manufacture 43(2003),pp-1419-1435