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# DESIGN AND INVESTIGATION OF SPRING LOADED TOOL IN METAL SPINNING PROCESS ON THE LATHE

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***Abstract*— This paper presents an advancement in the manual metal spinning process. The spinning machine consists of a mandrel mounted onto the headstock spindle. A workpiece on which operation is to be performed is gripped in between this mandrel and the tailstock (dead center). Final component formed by pressing blank over the mandrel. The operation is performed by a hand tool on a spinning lathe. The spinning process design still highly depends on experienced spinners using trial-and-error. Challenges remain to achieve high product dimensional accuracy and prevent material failures. This paper aims to convert this skilled work of metal spinning into a technique on the conventional lathe machine by employing Spring loaded roller tool and copying attachment. Lots of human effort required for this process in conventional spinning. The metal spinning machine with the lathe is a modification of the manual machine. By using this technique, the time and materials wasted by using the trial-and-error can be reduced significantly. Also, it gives a practical approach to standardized operation for the spinning industry and thus improves the product quality, process repeatability, and production efficiency.**

***Keywords*— Spinning, Roller, Blank, Mandrel, Forces, Spring-loaded tool**

## 1. INTRODUCTION

Spinning is commonly known as a process for transforming flat sheet metal blanks, usually with axisymmetric profiles, into hollow shapes by a tool that forces a blank onto a mandrel. The blanks are clamped rigidly against the mandrel using 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. The process is capable of forming components of diameters ranging from 3mm to 10m, and thicknesses of 0.4–25mm.

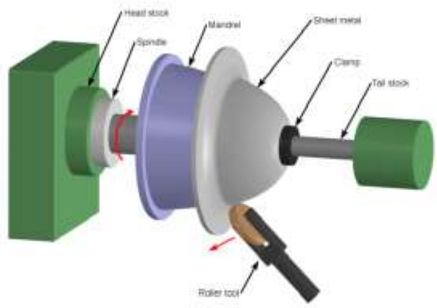


Fig. 1 Metal spinning process [2]

Spinning has several advantages when compared with these manufacturing methods. Localized deformation of the material under the roller requires low forming forces. Moreover, simple and non-dedicated tooling provides flexibility and has the potential for net shape forming. Lastly, formed components have a high-quality surface finish and improved mechanical strength.

## 2. DESIGN OF METAL SPINNING PARAMETERS

### 2.1 DESIGN WORKPIECE PARAMETER

**2.1.1 MATERIAL OF WORKPIECE:** This is the final component that is going to manufacture. To produce a component in metal spinning sheet metal is used. Almost all metal is available in the form of sheet, but the following metal is generally used in this process like aluminum, stainless steel, copper, brass, tin, silver, gold.

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

Table I shows the comparison of different grades of Aluminium. But we select an Aluminium

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1100 grade material for blank due to its good ductility and the high percentage of elongation.

Table I. Comparison of different grades of Al

| | Al 1100 – H14 | Al 3003 – H14 | Al 5052 – H32 | Al 6061 – T6 |
|---|---|---|---|---|
| **Aluminium percentage (%)** | 99 | 98 | 97 | 96 |
| **Elastic Modulus (GPa)** | 70-80 | 70 | 70.3 | 68.9 |
| **Tensile Strength (MPa)** | 110 | 160 | 228 | 310 |
| **Elongation (%)** | 60 | 30 | 25 | 25 |
| **Shear Strength (MPa)** | 69 | 96 | 138 | 207 |
| **Fatigue Strength** | 41 | 60 | 117 | 96.5 |

**2.1.2 COMPONENT DIMENSIONS:**

Large Radius of cone = 75 mm
Small Radius of cone = 35 mm
The slant height of cone = 57 mm
Half included angle of cone = 45deg.
Corner radius = 10mm
The thickness of sheet = 1mm

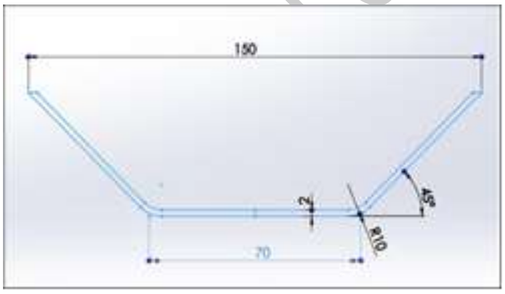


Fig. 2 Dimensions of the workpiece

**2.1.3 BLANK DIAMETER:** Blank diameter is a diameter of metal sheet which is used for producing spun component.
The surface area of blank = surface area of the cone [3]

$$\frac{\pi}{4}D^2 = \pi(R+r)S \quad (1)$$

Where, D = Diameter of blank

R = Large Radius of cone = 75mm
r = Small Radius of cone = 35mm
S = Slant height of cone = 57mm
Putting the values in equation (1)
D = 158.4 mm

**2.2 DESIGN TOOLING PARAMETER**

**2.2.1 ROLLER DIAMETER:** Roller acts as a tool that applies the force on the metal sheet over the mandrel. Rollers are available in different diameters and different thicknesses. According to Hayama, low mandrel speed, small roller diameter and low viscosity lubricant give a low surface finish. Roller diameter can be calculated by using the following formula.[6]

$$Dr = 0.1D + (D \pm R) \text{ mm} \quad (2)$$

Where,
Dr= Roller diameter in mm
D = Original diameter of blank in mm
= 158.4
R = Large Radius of cone= 75 mm

Dr =0.1*(158.36) + (150-75)
=95.836 mm

**2.2.2 ROLLER NOSE RADIUS:** The Roller nose radius has a significant effect on dimensional accuracy. Large the nose radius gives uniform thickness distribution and low surface roughness, which is applicable for conventional spinning.
Roller nose radius [6]

$$Nr = (0.012 \sim 0.05)\ D \quad (3)$$

Where,
D=Blank diameter in mm
Nr = (0.062) 158.4
Nr = 9.81 mm

Fig. 3 Roller

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**2.2.3 FORCES IN THE SPINNING PROCESS:** Most of the process of spinning is conducted by a trial and error basis. The force between the workpiece and Roller generated during shear forming can be resolved into three components, namely the axial (Fa), Radial (Fr) & Tangential (Ft). It has been experimentally observed that tangentially force is smaller than axial & radial forces. Most of the power supplied by the motors driving the chuck is translated through the tangential component.

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 [3]. 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 the convex roller path generally produces the lowest tool forces.

$F_a$ = Axial force
$F_r$ = Radial forces
$F_t$ = Tangential force

The Tangential force, [10]

$$F_t = (t_0 - C_s)\ \sin\alpha\ f \int \sigma\ d\sigma \qquad (4)$$

Where,

$t_0$ = Initial Blank thickness = 1mm
Cs= Over-roll Depth = 0.1mm
α= Half-cone angle = 45 degrees
f = Roller feed = 1 mm/rev
σ = Effective Stress
dϵ = Infinitesimal effective strain

According to Hooks law,

$$\sigma \ \alpha \ \epsilon$$
$$\sigma = E \times \epsilon$$

Where,

σ= Stress
ϵ = Strain
E = Young modulus of elasticity

For Aluminium,

$\sigma$= 110 MPa = 110 N/mm$^2$
E = 70 × 10$^3$ N/mm$^2$

$$\epsilon = \frac{\sigma}{E} = \frac{110}{70 \times 10^3} = 1.5714 \times 10^{-3}$$

$$F_t = (t_0 - C_s)\ \sin\alpha\ f\ E \int \epsilon\ d\epsilon$$

$$F_t = (t_0 - C_s)\sin\alpha\ f\ E\ (\frac{\epsilon^2}{2})$$

$$F_t = (1 - 0.1)\ \sin 45\ (900)\ (70 \times 10^3)\ \frac{(1.5714 \times 10^{-3})^2}{2}$$

$F_t$ = 49.493 N

Axial force
$F_a = 17 \times F_t$ = 841.38 N

Radial force
$F_r = 5 \times F_t$ = 247.46 N

**2.2.4 SPRING LOADED ROLLER TOOL:** A rigid tool is used to exercise manual spinning operation, which completely is predicated on one's skills. The equal practice is conducted on a manual lathe machine which results in material failure. Hence a soft tool, which is spring-loaded is required to overcome defects of the rigid tool. The spring used with this tool enables it to move back from sheet metal whenever force exceeds from maximum spinning force limit. The spring-loaded tool is shown in fig.4.

Fig. 4 Spring-loaded roller tool

To set the dimensions of spring, we calculate the value of maximum force induces in the spinning process. From calculation we can conclude that maximum force induces in conventional spinning is 841.38 N. As per our force value, it is required to select a helical compression spring subjected to a maximum force of 841.38 Newton. The deflection of the spring corresponding to the maximum force

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should be approximately 10 mm. The material of the spring is stainless steel. The ultimate tensile strength and modulus of rigidity of the spring material are 2050 and 81370 N/mm$^2$ respectively.

From calculations the following dimensions we get,
Wire diameter = 4 mm
Mean coil diameter = 24 mm
Number of active coils = 3
Total number of coils = 5
Free length of spring = 37.4 mm
Pitch of the coil = 9.35 mm

**2.2.5 MANDREL:** The 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 the shape of the final component, the mandrel is designed. With the assist of the 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 the material used for mandrel is cast iron, mild steel, Aluminium, Magnesium, and plastic coated wood. When it is necessary to produce parts to close tolerances, the mandrels are normally made of steel and cast iron, cored casting of steel, or cast iron is preferred to reduce the rotating weight. Mandrels must be statically balanced, and when used at high speed and the mandrels should also dynamically balance.

As we want to produce a cone-shaped component having 150 mm diameter according to this requirement we design the mandrel having

Large diameter=150mm
Small diameter=70mm
Slant height=57mm

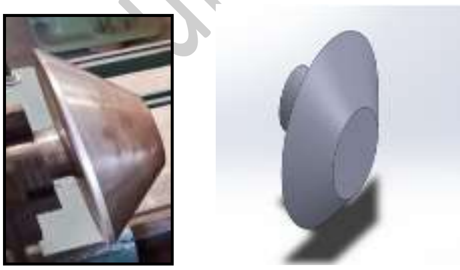

Fig. 5 Mandrel

## 2.3 DESIGN PROCESS PARAMETER

**2.3.1 FEED RATIO:** Feed ratio is described as the ratio of the roller feed rate to the spindle speed. The quality of the product depends on the feed ratio. As long as the feed ratio remains constant, the roller feed rate and the spindle speed can be changed. High feed ratios generate higher forces that may result in cracking. In contrast, too low a feed ratio will cause more material flow in an outward direction, which unnecessarily reduces work-ability and unduly thins the wall. Low feed ratio is preferred before high feed ratio in the spinning process because it is a better option since a good surface and no failure of the component takes place. For Aluminium, feed ratio is 0.9 mm/rev and for mild steel, feed ratio is 1.8 mm/rev [9].

**2.3.2 FEED RATE:** One of the major parameters in this process is the roller feed rate. It affects the formability and forming quality. Technically it is the distance of the tool that advances into or along with the workpiece each time is. It is measured in mm/sec or mm/ min. High feed rate gives rough surface finish & wrinkling. A low feed rate gives a high surface finish while a high or increased feed rate will make a workpiece fit the mandrel [10]. Due to high feed rate, rough surface finish and wrinkling occur, this is the main drawback of high feed rate.

**2.3.3 SPINDLE SPEED:** According to Hayama, the effect of mandrel speed on to the tool forces is very less, almost negligible. Due to this negligence a wider range of feasible mandrel speed is possible. The impact of rotational speed on the variation of axial and radial forces is negligible[6]. For aluminum material, we take Spindle speed 125 to 380 pm
N= (9500~320000)/Do
Where,
N=Mandrel speed in RPM
Do= original blank diameter in mm
N=60000/158.4=380 rpm

**2.3.4 LUBRICANTS:** A lubricant is used for supplying lubrication between surfaces under friction which produces an immense quantity of heat. A lubricant is always used during spinning. The fluid used serves as both a lubricant and coolant. When spinning aluminum, stainless steel, or titanium, the workpieces or mandrels or both are sometimes coated with the lubricant before spinning. The lubricant ought to continue to adhere to the rotating preform during spinning. Most of the

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time cup grease is used [3]. Viscosity is a vital parameter of a lubricant. To reduce the viscosity, a lubricant can be heated. Reduced viscosity helps in the easy application of the lubricant.

## 3. EXPERIMENTAL SETUP FOR TRIAL

In fig.6 under we can see mandrel, chuck, tailstock live center, and tailstock. The mandrel is held within the chuck and the tailstock live center is held in the tailstock. The use of chuck is to rotate the mandrel with a certain speed & tailstock live center support the mandrel. Tool holding block is used to hold the tool & travel the tool in the direction of the workpiece.

Fig. 6 Experimental setup

The spring-loaded roller is the tool that is in contact with the workpiece. The blank is clamp between mandrel male and live center female part. When spindle speed is given to mandrel then mandrel and blank start rotating together alongside live-center at high speed. The spring-loaded tool is guided according to the mandrel by using copying attachment.

Before conducting experiments we take into account certain process parameters, as the feed rate of the tool per revolution was changed from 0.2 mm to 0.4 mm. Experiments conducted in a single pass by using copying attachment. Tool profile with a large nose radius would lead to a smaller reduction of wall thickness. We consider the tool of nose radius 9.81 mm for all the experiments.

The parameters and their values are shown in Table II.

Table II. Parameters for process

| | | | |
|---|---|---|---|
| **Material of workpiece** | Al1100 | **Roller nose radius (mm)** | 9.81 |
| **Blank diameter (mm)** | 158.4 | **Spindle speed (RPM)** | 380 |
| **Blank thickness (mm)** | 1 | **Feed rate (mm/rev)** | 0.2-0.4 |
| **Roller diameter (mm)** | 95.83 | **Mandrel diameter (mm)** | 150 |

## 4. RESULT AND DISCUSSION

In traditional spinning, component accuracy depends on the worker's skill. By modifying the setup we take a trial and produce the final component without any crack and wrinkle. The final component is shown in Figure 7.

Fig. 7 Final Component

Tool profile with a large nose radius would cause a smaller reduction of wall thickness. Thinning of sheet material taking place in each test as there is a big difference between the initial thickness and the final thickness of the sheet at the crack point. When the roller tool without spring is used, defect occurring in front of us is circumferential cracking mainly in the area close to the mandrel. The component which was spun using the spring-loaded tool gives more deformation before cracking but results in wrinkling failure. It has been found that more cup depth can be produced with a spring-loaded tool. By proper designing of copying attachment and spring-loaded tool, the accuracy of the workpiece can be increased.

By using this technique, the time and materials wasted by using the trial-and-error can be reduced significantly. Also, it may provide a practical approach to standardized operation for the spinning industry and thus enhance the product quality, process repeatability, and production efficiency. This will help to make the spinning technique independent of the skilled spinner.

## 5. CONCLUSION

In the conventional technique, the worker had to apply a lot of force while in process with the carriage, worker's efforts are decreased and very much less force is to be applied. Also using the above design parameters we should reduce the defect & failure that occurs in metal spinning operation performed with the lathe. Using a large nose radius high surface quality is achieved. If a good machine is available then the working time is also decreased highly. Experiments were conducted to find out the forces involved in the spinning operation and a spring-loaded tool has been developed. The spring-loaded tool allows obtaining circumferential crack free parts but results in wrinkling failure. Thinning of sheet material at failure is found to be 30 % in both the components formed with the help of conventional tool and spring-loaded tool. The cup depth can be increased using a spring-loaded tool. A skilled worker can produce components with very good surface finish and high accuracy. The tool movement is guided by copying attachment, so it can be automated by copying attachment. So a very perfectly precise product can be obtained.

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