

MODELLING OF SPINNING PROCESS WITHOUT WALL-THICKNESS REDUCTION ON DOME FORMING

Sandeep Shukla¹, Dr. Somnath Chattopadhyaya²

¹Department of MECH(Manufacturing), Indian Institute of Technology (ISM)

Dhanbad, Jharkhand (India)

²Associate Professor, Dept of Mech. Engg. ,Indian Institute of Technology (ISM),

Dhanbad, Jharkhand (India)

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. 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 project aims to gain insight into the modeling of spinning process without wall-thickness reduction on dome forming. By the effects of roller path profiles –a spinning process parameter. Using a concave roller path produces high tool forces, stresses and reduction of wall thickness. Conversely, low tool forces, stresses and wall thinning have been obtained uses the convex roller path.

Keywords: Axisymmetric; Dome forming; Wall-thickness; Roller path.

I. INTRODUCTION

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, bearing 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 (Runge, 1994). The process is capable of forming a work piece 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 mechanical properties of the spun part.

There are two types of sheet metal spinning: in conventional spinning, a blank is formed into the desired shape by multiple roller passes to maintain the original wall thickness (t_0); however, the diameter of the spun part (D_1) has been reduced from the original diameter (D_0). Conversely, during shear forming, the roller deforms the blank by one single pass as shown in Figure 1.3(b). The diameter of the spun part (D_1) remains unchanged but the wall thickness of the spun part is reduced deliberately. The final thickness of the spun part, t_1 , can be determined by the sine law. $t_1 = t_0 \cdot \sin \alpha$ where t_0 is the original thickness of the blank, α is the inclined angle of the mandrel.

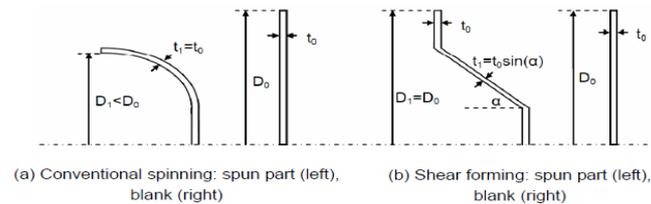


FIGURE 1: Conventional spinning and shear process.

During the conventional spinning process, a local plastic deformation zone is generated at the roller contact area. The stress patterns of this zone depend on the roller feeding direction (Runge, 1994). In the forward pass (the roller feeds towards the edge of the blank), tensile radial stresses and compressive tangential stresses are induced).

The tensile radial stresses lead to a material flow towards the edge of the blank causing thinning of the blank, which is balanced by the thickening effects of the compressive tangential stresses, maintaining an almost constant thickness. In the backward pass (the roller feeds towards the mandrel), however, the material builds up in front of the roller, generating compressive radial stresses and compressive tangential stresses. There are three types of common material failures in the sheet metal spinning process (Wong et al., 2003): wrinkling, circumferential cracking and radial cracking.

Wrinkling is caused by buckling effects of the unsupported flange of the metal sheet during spinning. Once the compressive tangential stress in the work piece exceeds a buckling stability limit, wrinkling will occur. Therefore, multiple roller passes are generally required in order to keep the compressive tangential stress below the buckling limit. In the sheet metal spinning process, excessive stresses in either radial or tangential direction of the spun part are undesirable. High tensile radial stresses lead to the circumferential cracking failure, mainly in the area close to the mandrel. The radial cracking is normally caused by the bending effects over existing severe wrinkles.

This chapter consists of three main sections which review the published literature of studies on sheet metal spinning.

In Section 2.1, three main investigation techniques in the research of metal spinning, i.e. theoretical study, experimental investigation and FE analysis are presented.

1.1 Investigation Techniques

In this section, the methodology of theoretical analysis and experimental investigation on the tool forces, strains and material failures of the spinning process are reviewed. Moreover, the key Experiments using a range of CNC roller path designs. Roller path profiles have been selected for analyzing their effects on the material thickness (blank thickness) of the conventional spinning process.

On the basis of first trial of roller path profile graph can be obtained through MINITAB

Graph is compared between normalized radial distance and thickness of blank

factors in the FE simulation, such as FE solution methods, material constitutive model, element selection, meshing strategy and contact treatment, are discussed in detail.

1.1.1 Theoretical Study

Compared with the limited theoretical studies on the strain and wrinkling failure, most of the research work focuses on the theoretical analysis of tool forces, where eight analytical force models are identified in this literature review. However, all of these analytical force models are developed for the shear forming but not for conventional spinning.

Analysis of Tool Forces

In those eight published papers, the deformation energy method has been used to predict the tool forces, i.e. the work done by the external force is assumed to be equal to the deformation energy of the work piece. Most of the analytical models developed in 1960s only took the tangential force component into account (Avitzur and Yang, 1960, Kalpakcioglu, 1961a, Sortais et al., 1963). This is because the tangential force consumes most of the power in the spinning, and it is thus significantly important for the design of spinning machines. Researchers (Avitzur and Yang, 1960, Kim et al., 2003, Kobayashi et al., 1961) calculated the tool force based on the assumption that the deformation mode in spinning is a combination of bending and shearing. Moreover, by assuming uniform roller contact pressure, Kobayashi et al. (1961) estimated the radial and axial forces from the projected contact areas. A similar approach has also been employed by Chen et al. (2005a), Kim et al. (2006) and Zhang et al. (2010).

F_a = Axial force

F_r = Radial forces

F_t = Tangential force

The Tangential forces are as follow

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

We know that,

t_0 = Initial Blank thickness

C_s = Over-roll Depth

α = Half-cone angle

f = Roller feed

σ = Effective Stress and

de = Infinitesimal effective strain

According to Hooks law,

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

Where, σ = Stress ϵ = Strain E = Young modulus of elasticity.

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

$$F_A/F_T=17:1$$

The ratios between maximum Radial forces to maximum tangential forces 5:1

$F_r/F_t=5:1$

Experimental Investigation

Experimental investigation has been applied to analyse the material deformation and failure in the sheet metal spinning process since the 1950s. In this literature review, 39 papers of experimental investigation in sheet metal spinning are included. The methodologies of measuring tool forces, investigating strains and material deformation, and analysing material failures are presented in this section. The statistical experimental design methods that have been used in spinning research are also discussed.

Roller Path and Passes

multiple roller passes in conventional spinning, the tensile radial and compressive tangential stresses are induced gradually; hence material failures can be prevented (Runge, 1994, Sebastiani et al., 2007). Up to now, most investigations of roller path and passes in conventional spinning have focused on single pass or multi-pass with no more than 3 passes (mainly linear path). Consequently, there is still a huge knowledge gap between academic research and industrial production, where a considerable amount of roller passes have to be used to successfully produce complicated spinning parts (Filip and Neago, 2010). Three types of the roller path shown in Figure 2.3, straight line, concave curve and convex curve, have been experimentally studied by Kang et al. (1999) and Hayama et al. (1970). The difference between these two experiments was that only the single pass was studied by Kang et al.; whereas multiple passes were investigated by Hayama et al. Kang et al. (1999) concluded that the first pass in the conventional spinning plays a decisive role in the final blank thickness. After comparing four different types of roller path designs, Hayama et al. (1970) proposed that the involute curve path, which is a special type of concave curve, gives the highest spinning ratio without material failures. This was supported by Liu et al. (2002), who numerically analyzed the distributions of stresses and strains obtained from three different roller paths, i.e. straight line, involute curve and quadratic curve. Their FE analysis results illustrate that the stresses and strains obtained under the involute roller path are the smallest. Furthermore, Kawai and Hayama (1987) applied an involute curve in each pass in their experiments and studied the first pass and the remaining passes separately. They suggested that the angle of the first pass plays a dominant role in the generation of wrinkles and cracks.

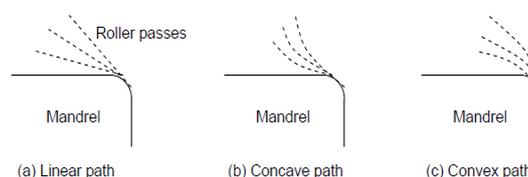


FIGURE 2: Various roller path profiles.

Roller Profile

various shapes of spinning roller (Avitzur et al., 1959). Roller diameter and nose radius are two key parameters that have been investigated by a few researchers. According to the literature review by Wong et al. (2003), the roller diameter has little effect on the final product quality, but a small roller nose radius would result in poor thickness uniformity. This is supported by El-Khabeery et al. (1991), who reported that an increase in roller nose radius would lead to a smaller reduction of wall thickness. Younger (1979) claimed that increasing the roller nose radius resulted in a decline of the axial force and had almost no effects on the variations of tangential

force in a shear forming experiment. Both Essa and Hartley (2010) and El-Khabeery et al. (1991) pointed out that as the roller nose radius decreased, tool forces would go down accordingly in one-pass deep drawing conventional spinning. In a multi-pass conventional spinning experiment, Wang et al. (1989) also reported that all of the three tool force components decrease when applying a smaller roller nose radius. to an experimental wrinkling study in the shear forming, Hayama et al (1966) reported that the roller nose radius had little effects on the wrinkling failures in the shear forming process. Chen et al. (2001), El-Khabeery et al. (1991) and Kleiner et al. (2005) pointed out.

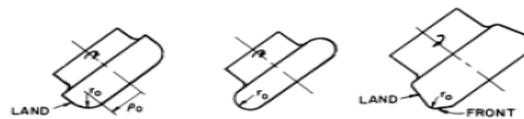


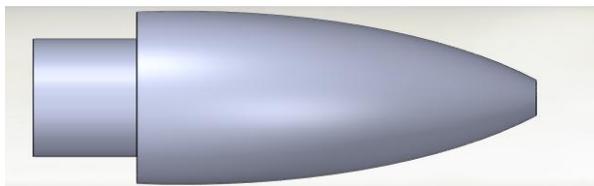
Figure 3: Various roller profile.

that increasing the roller nose radius would improve the surface finish of the spun part. Chen et al. (2001) suggested that a larger roller nose radius resulted in a larger contact area between roller and blank, thus producing a smoother material deformation

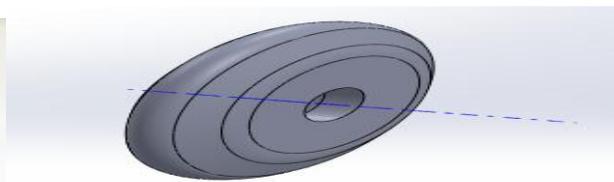
MODELLING OF SPINNING COMPONENTS

The model of components is done using cad software tool like Solid Works. This software is developed by Dassault Systemes. The features in this software are user friendly. Various features like Boss Extrude, Loft, Sweep pattern, Shell, Draft, Revolve base. The advanced Assembly feature enables us to assemble components with precision.

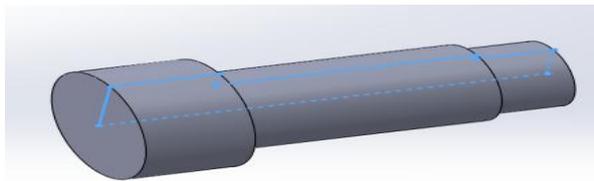
Mandrel



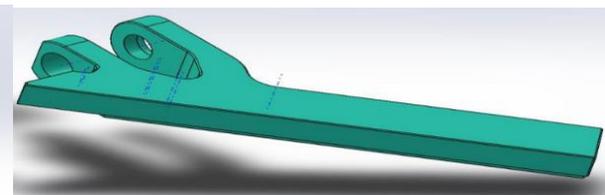
ROLLER



Back plate



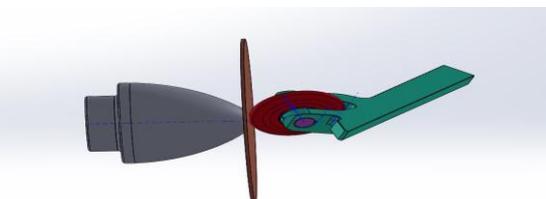
Fork



Blank



Final Assembly



Experimental Trails

The main objective of project is to modeling of spinning process without wall-thickness reduction on dome forming shell.

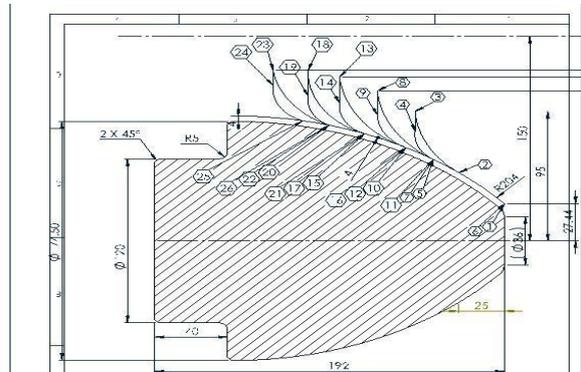
For this project the trials are done on CNC spinning machine, for maximum no of trial a 4 mm thickness blank is required having diameter 356 mm.

During experiment first we cut the copper plate of 4 mm thickness having diameter 356 mm by WATER JET MACHINING and then that plate is prepared for central trial in CNC spinning machine after that we gives the CNC programming (roller path).

TRAIL 1

S. N O	Mater ial	Thickne ss	Diamet er	Feed	Speed
1	Pure coppe r	4 mm	356 mm	0.06 mm/ rev	150 rpm

Blank- Pure Copper

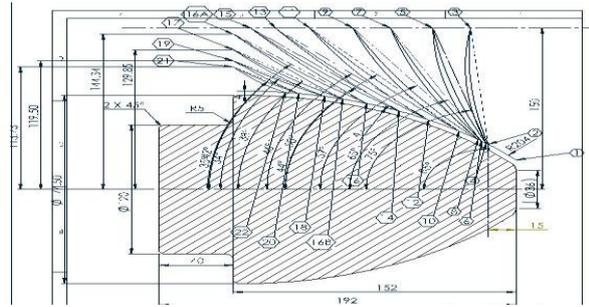


Roller Path Profile Final component formed



TRAIL 2

S.NO	Material	Thickness	Diameter	Feed	Speed
1	Pure copper	4 mm	356 mm	0.1 mm/rev	219 rpm



Blank- Pure Copper Roller Path Profile

Final Component Formed



RESULTS

Experiments using a range of CNC roller path designs. Roller path profiles have been selected for analyzing their effects on the material thickness (blank thickness) of the conventional spinning process.

On the basis of first trial of roller path profile graph can be obtained through MINITAB

Graph is compared between normalized radial distance and thickness of blank.

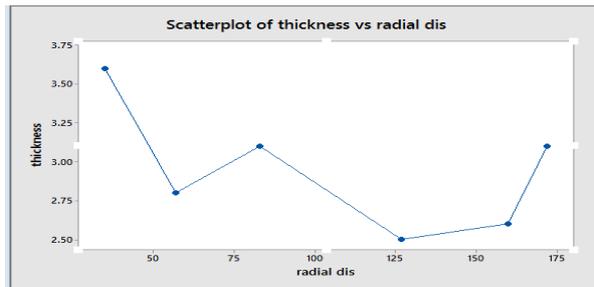


Figure:1

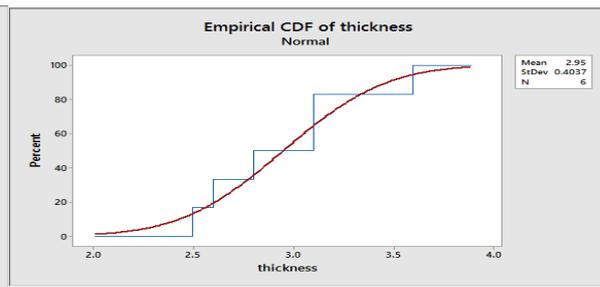


Figure:2

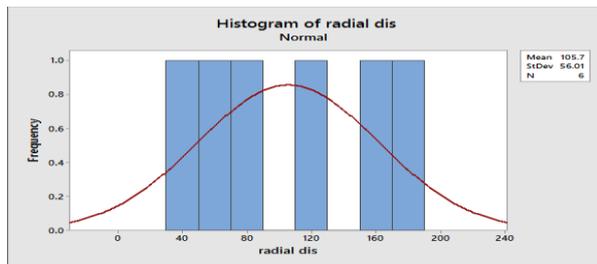


Figure:3

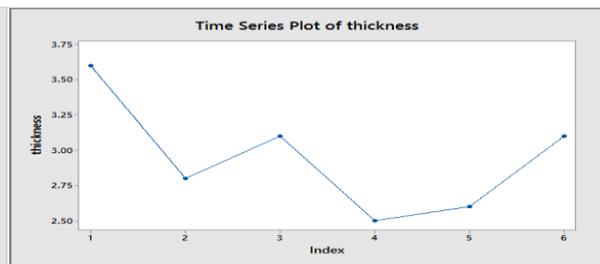


Figure :4

II. CONCLUSION

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. A Greater Curvature Of The Concave Path Would Result In A Higher Amount Of Wall Thinning Of The Spun Part.

REFERENCES

- [1] G Dieter, Engineering Design - a materials and processing approach, McGraw Hill, NY, 2000.
- [2] John A. Schey, Introduction to manufacturing Process, McGraw Hill, NY, 2000.
- [3] Kalpakjain, Manufacturing Processes for Engineering Materials, Pearson Education, 2007.
- [4] WANG, L. & LONG, H. 2011b. Investigation of material deformation in multi-pass conventional metal spinning. *Materials & Design*, 32, 2891-2899
- [5] WANG, L. & LONG, H. 2011c. A study of effects of roller path profiles on tool forces and part wall thickness variation in conventional metal spinning. *Journal of Materials Processing Technology*, 211, 2140-2151
- [6] WANG, L. & LONG, H. 2011c. A study of effects of roller path profiles on tool forces and part wall thickness variation in conventional metal spinning. *Journal of Materials Processing Technology*, 211, 2140-2151
- [7] SHIMIZU, I. 2010. Asymmetric forming of aluminum sheets by synchronous spinning. *Journal of Materials Processing Technology*, 210, 585-592.
- [8] REITMANN, V. & KANTZ, H. 2001. Plastic wrinkling and flutter in sheet metal spinning[Online]. Available: <http://www.vreitmann.de/reitmann/wrinkling.html> [Accessed 15 February 2011].
- [9] TIMOSHENKO, S. 1936. *Theory of elastic stability*, New York ; London, McGraw-Hill Book Company, inc..
- [10] TIMOSHENKO, S. & WOINOWSKY-KRIEGER, S. 1959. *Theory of plates and shells*, New York, McGraw-Hill book company