A STUDY ON DEEP DRAWING AND SPINNING PROCESS IN SHEET METAL FORMING

Dr.R.Uday Kumar

Associate professor, Dept. of Mechanical Engineering, Mahatma Gandhi Institute of Technology, Gandipet, Hyderabad. 500075. Andhra Pradesh. India.

ABSTRACT

Sheet metal forming is a significant manufacturing process for producing a large variety of automotive parts and aerospace parts as well as consumer products. The sheet metal operations such as shearing, blanking, piercing, notching, trimming and nibbling. The sheet metal processes are bending, embossing, coining, spinning, stretch forming and deep drawing. Deep drawing is a compression-tension forming process involving wide spectrum of operations and flow conditions. The result of the process depends on the large number of parameters and their interdependence. In the process of spinning, an object with surface of revolution is produced from a sheet metal. The blank is held against a form die which is rotated and the sheet metal blank is laid over this die, using a specially shaped tool or roller. If a simultaneous thinning of the sheet metal takes place during the operation, the process then is called shear spinning. A theoretical study is made on forming processes particularly in spinning and deep drawing. According to the literature survey a lot of research is still require to completely understand the technology of metal spinning, calculation of the forces based on plasticity theory have been attempted but have not yet brought satisfactory results. In the situation the spinning process is very similar to deep drawing. The spinning process also enables components to be produced with both improve mechanical properties of almost 2 to 2.5 times their values 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 components. In this paper author studied to present the available literature on this subject the present state of art of deep drawing and spinning process in its industrial applications. It will be guidance for the practical production engineers engaged in this spinning area. This paper also contains the comparative study of spinning and deep drawing process.

Keywords: Deep drawing, spinning, sheet metal forming processes

1. INTRODUCTION - DEFORMATION PROCESS

Metal forming process are classified into bulk forming processes and sheet metal forming processes .In both types of process, the surface of the deforming metal and tools in contact, and friction between them may have a major influences on material flow. In bulk forming the input material is in billet, rod or slab form and the surface the volume ratio in the formed part increases considerably under the action of largely compressive loading. The bulk forming processes are rolling, forging, wire drawing and extrusion. In this forming processes ratio of volume to surface area and ratio of volume to thickness are high. Sheet metal forming is a significant manufacturing process for producing a large variety of automotive parts and aerospace parts as well as consumer products. In this process piece of sheet metal is plastically deformed by tensile load into three dimensional shapes, after without significant changes in sheet thickness or surface characteristics. The sheet metal operations as shearing, blanking, piercing, notching, trimming and nibbling.

The sheet metal process are bending, embossing, coining, spinning, stretch forming and deep drawing. The literature tends to concentrate on the study of deformations, stresses, and forces prevailing during the operation. Both experimental and analytical studies are available. Sieblel's [1] brief article describes the operation of spinning in general. It gives experimental graphs of the maximum radial and maximum axial forces as function of wall thickness, roller curvature, and diameter ratio or outer bend radius.The tangential force is computed through the power consumption.This power consumption is computed under the assumption that the material mediate distortion. In other words, the path of the deformations is neglected; only the end points are considered and the ideal deformation is assumed, neglecting redundant power and friction losses. No experimental data are given for tangential force.

Reichel [2] starts by comparing deep drawing to power spinning of cones.He then describes the deformation pattern in power spinning stresses the importance of the sin law. He points out that, with the sine law, the deformation and stresses take place only under the instantaneous area of contact, and the rest of the material is strain-free. Reichel attempts an explanation of experimental graphs of the radial and feed forces as function of some of the variables. The explanation is based on a calculation of an approximate area of contact. The author admits that this is not the only

factor, and points out that some trends can not be explained this way. He also says that no effect of the lubricant on the measured forces was found. No attempt to compute power and tangential force was made.
The work is mostly an experimental study to determine the radial and feed forces. The effects of process variables on the buckling and bending of the flange is also discussed. A study of the pattern of deformation is included. Some discrepancies between his conclusions and more recent findings may be attributed to the fact that sine law was not observed.
Some pioneering work in the study of the spinning of cone was conducted at the university of California, berkely and at the Cincinnati milling machine co. Experimental studies of the both the flow patterns and the spinning forces are presented and some analysis for the prediction of spinning forces is then performed.

2. DEEP DRAWING PROCESS

One of the important sheet metal forming process is deep drawing which has been used in a wide range of industrial applications for converting the sheet into the hallow work piece. Deep drawing of metal sheet is used to form containers by a process in which a flat blank is constrained while the central portion of the sheet is pressed into a die opening to draw the metal into the desired shape without folding of the corners. This generally requires the use of presses having a double action for hold down force and punch force[3-8]. The process is capable of forming circular shapes, such as cooking pans, box shapes, or shell-like containers. The term deep drawing implies that some drawing – in of the flange metal occurs and that the formed parts are deeper than could be obtained by simply stretching the metal over a die. Clearance between the male punch and the female die is closely controlled to minimize the free spam so that there is no wrinkling of the side wall. This clearance is sufficient to prevent ironing of the metal being drawn into the sidewalls is to be part of the process; it is done in operations subsequent to deep drawing. Suitable radii in the punch bottom to side edge, as well as the approach to the die opening, are necessary to allow the metal sheet to be formed without tearing. In most deep drawing operations, the part has a solid bottom to form a container and a retained flange that is trimmed later in the processing. In some cases, the cup shape is fully drawn into the female die cavity, and a straight-wall cup shape is ejected through the die opening. To control the flange area and to prevent wrinkling, a hold-down force is applied to the blank to keep it contact with the upper surface of the die. A suitable sub press or a double-action press is required. Presses can be either hydraulic or mechanical devices, but hydraulic presses are preferred because of better control of the rate of punch travel.

2.1 Principle of deep drawing process

Classification of the Deep drawing process based on the type of force application, the deep drawing processes can be divided into three methods : 1) deep drawing with tools 2) deep drawing with an active medium 3) deep drawing with active energy. A flat blank is formed into a cup by forcing a punch against the center portion of a blank that rests on the die ring. The progressive stages of metal flow in drawing a cup from a flat blank are shown schematically in fig.1. During the flat stage, the punch contacts the blank [Fig.1 a], and metal section 1 is bent and wrapped around the punch nose [Fig.1b). Simultaneously and in sequence, the outer sections of the blank (2 and 3, Fig.1) move radially toward the center of the blank until the remainder of the blank has bent around the punch nose and a straight – wall cup is formed (Fig.1c and1d). During drawing, the center of the blank (punch area, Fig.1a) is essentially unchanged as it forms the bottom of the drawn cup. The areas that become the sidewall of the cup (1,2 ,and3, Fig.1) change from the shape of annular segments to longer parallel-side cylindrical elements as they are drawn over the die radius. Metal flow can occur until as the metal has been drawn over the die radius, or a flange can be retained. As the blank is drawn radially inwards the flange undergoes radial tension and circumferential compression. The latter may cause wrinkling of the flange if the draw ratio is large, or if the cup diameter-to-thickness ratio is high. A blank holder usally applies sufficient pressure on the blank to prevent wrinkling .Radial tensile stress on the flange being drawn is produced by the tension on the cup wall induced by the punch force. Hence, when drawing cups at larger draw ratios, larger radial tension are created on the flange and higher tensile stress is needed on the cup wall. Bending and unbending over the die radius is also provided by this tensile stress on the cup wall. In addition, the tension on the cup wall has to help to overcome frictional resistance, at the flange and at the die radius. As the tensile stress that the wall of the cup can withstand is limited to the ultimate tensile strength of material.
A blank holder is used in a draw die to prevent the formation of wrinkles as compressive action rearranges the metal from flange to sidewall wrinkling starts because of some lack of uniformity in the movement or because of the resistance to movement in the cross section of the metal. A blank holder force sufficient to resist or compensate for this no uniform movement prevents wrinkling. Once a wrinkle starts, the blank holder is raised from the surface of the metal so that other wrinkles can form easily. The force needed to hold the blank flat during drawing of cylindrical shells varies from practically zero for relatively thick blanks to about one third of the drawing load for a blank 0.76mm thick. Thinner blanks often require proportionality greater blank holder force. The blank holder pressure should be only high enough to prevent wrinkling of the metal. A too high value of blank holder pressure causes higher frictional forces and may cause the metal to be restricted and may result in tearing of the cup wall [9-18].

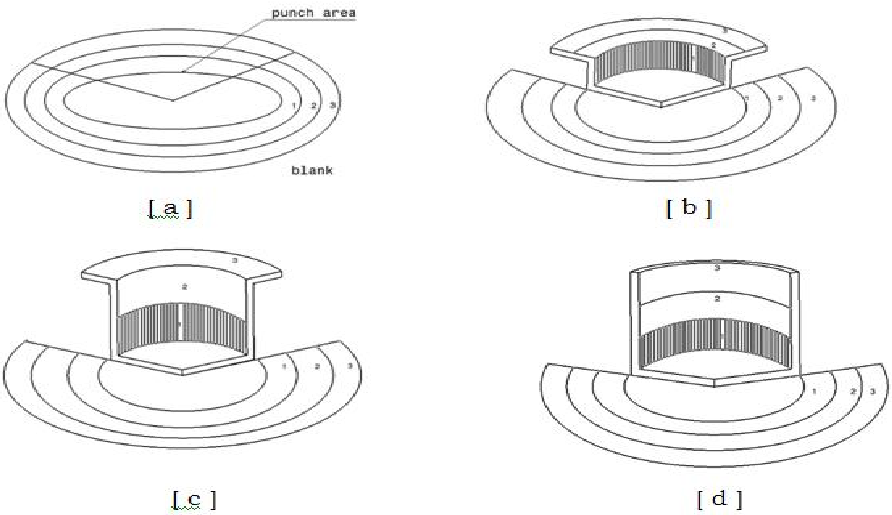

Fig.1 Progression of metal flow in drawing a cup from a flat blanks

Drawing speed is the velocity at which the punch penetrates work piece. It often has a definite effect on drawing operation. When cracking or excessive thinning occurs the drawing speed should be reduced. In general the drawing speed should be less for harder and more ductile materials. Die clearance is the gap left between the punch and die. The clearance is are usually 7 to 14% greater than sheet thickness and this is for safe of sheet metal. If the clearance is too small, the blank may simply be pierced or sheared by the punch. The various types of common deep drawing defects are flange wrinkles, wall wrinkles, fractured rim and bottom, corner fracture, directional earing and miss strike. In this process the portion of the blank between the die wall and the punch surface is subjected to nearly pure tension and tends to stretch and become thinner. The portion of the formed cup, which wraps around the punch radius is under tension in the presence of bending. This part becomes the thinnest portion of the cup.This action is termed as necking and in the presence of unsatisfactory drawing operation, is usually the first place to fracture.

Drawing ratio of the metal is defined as the ratio of the maximum blank diameter to diameter of the cup drawn from the blank it is equal to D/d this called limiting drawing ratio. This ratio depends upon many factors. Such as type of material amount of fraction present etc. The usual range of the maximum drawing ratio is 1.6 to 2.3.

3. SPINNING PROCESS

Spinning is to process used for making cup shaped articles which are axisymmetrical. Two process of spinning consisting of rotating two blank, fixed against the form block and then applying a gradually moving force on the blank takes the shape of the form block. During spinning the tools are moved relative to the rotating work piece [19-23]. Spinning belongs to the tension and compression forming processes since tangential compressive and radial tensile stresses are generated in the deformation zone just as in deep drawing. It has become necessary to study the process variable and their effect on the product to eliminate costly errors in the trial and error method. The increase in civilian and military items produced by power spinning also explain why more attention has latterly been directed to the study of this process. The spinning process as shown in fig.2

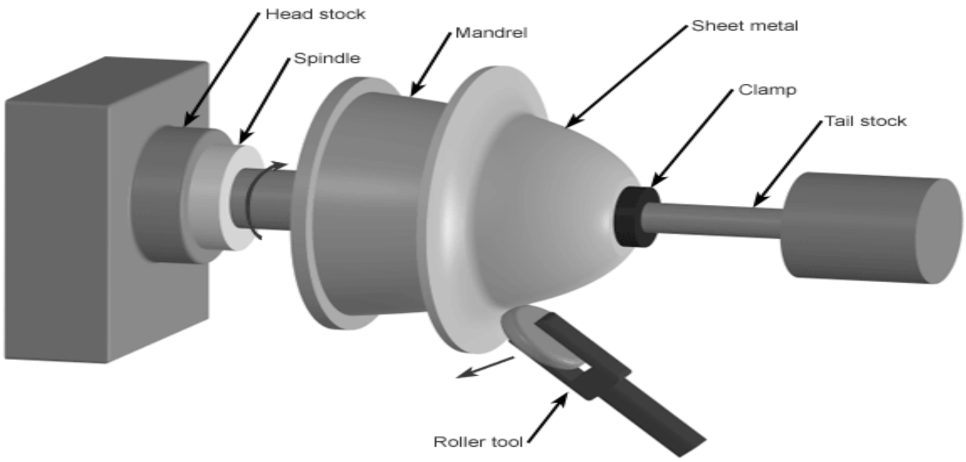

Fig.2 Spinning process

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The work piece is shaped with a rolled in several increments until the final shape is achieved for smaller work pieces it is possible to use a forming bar in place of the roller. The forming processes can also be carried out in a single step. This spinning process is very similar to deep drawing. However forming does not take place along the entire circumference at once but is limited to small region near the roller. A material element in the deformation zone loaded by radial tensile and tangential compressive stresses. The stresses are analyzed by using trescas flow criterion in this process. In the wall of the work piece there are axial tensile stresses. Analogous to the drawing ratio is the ratio of initial diameter to final diameter of product is called the spinning ratio. it is denoted by β.

If the spinning ratio is very large or if the edge radius of roller is small then the axial thrust force of the roller can generate very high tensile stresses in the wall which cannot be transmitted by the corresponding portion of the cup cross section. In this case tangential cracks will appear in the transition from flange to the wall.

Radial cracks can form in the outermost portion of the flange at the end of the process when wrinkles are removed by continued spinning. The resulting alternating bending stresses can cause cracks. This is due to higher in β. This drawing ratio depends on the sheet thickness, diameter and radius of roller.

During the spinning the flange is supported only in the region of the tool is free over the remainder of the circumference. Thus the tendency to buckle and to form wrinkles is greater here than it is in deep drawing. The limiting spinning ratio is reached when the waves (wrinkles) in the flange become so large that they can not be removed by subsequent passes of the tool. Due to compressive tangential stresses the flange tries to buckle. The roller exerts a force on the work piece with components in the radial, axial and tangential directions. The tangential force component is generally small and can be neglected [24-27].

There are two distinct spinning methods, referred to as conventional spinning and shear spinning. These are as shown in fig.3. 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 blank, but will maintain a constant thickness. 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. By doing so, the outer diameter of the spun part will remain equal to the original blank diameter, but the thickness of the part walls will be thinner.

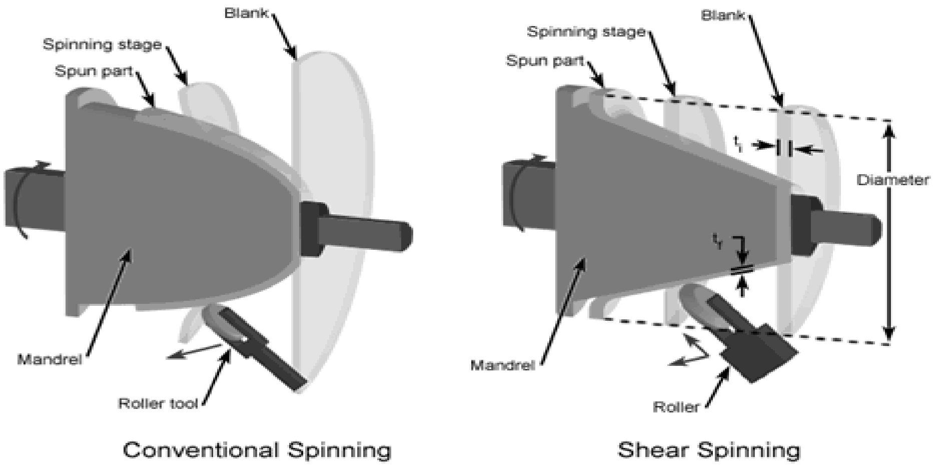

Fig.3 Conventional Spinning and Shear Spinning process

The Spinning, sometimes called spin forming, is a metal forming process used to form cylindrical parts by rotating a piece of sheet metal while forces are applied to one side. A sheet metal disc is rotated at high speeds while rollers press the sheet against a tool, called a mandrel, to form the shape of the desired part. Spun metal parts have a rotationally symmetric, hollow shape, such as a cylinder, cone, or hemisphere. Examples include cookware, hubcaps, satellite dishes and rocket nose cones. Spinning is typically performed on a manual or CNC lathe and requires a blank, mandrel, and roller tool. The blank is the disc-shaped piece of sheet metal that is pre-cut from sheet stock and will be formed into the part. The mandrel is a solid form of the internal shape of the part, against which the blank will be pressed. For more complex parts, such as those with reentrant surfaces, multi-piece mandrels can be used. Because the mandrel does not experience much wear in this process, it can be made from wood or plastic. However, high volume production typically utilizes a metal mandrel. The mandrel and blank are clamped together and secured between the headstock and tailstock of the lathe to be rotated at high speeds by the spindle. While the blank and mandrel rotate, force is applied to the sheet by a tool, causing the sheet to bend and form around the mandrel. The tool may make several passes to complete the shaping of the sheet. This tool is usually a roller wheel attached to a lever. Rollers are available in different diameters and thicknesses and are usually made from steel or brass. The rollers are inexpensive and experience little wear allowing for low volume production of parts.

4. DIFFERENCES BETWEEN SPINNING AND DEEP DRAWING

Spinning process	Deep drawing process
1. Roller force is acting in three directions tangentially, axially and radial	1. Punch force is acting in downwards
2. Wrinkle defects is more	2. Wrinkle defects is less comparatively spinning
3. Tangential compressive stresses generated in deformation zone	3.Circumferential compressive stresses generated in deformation zone
4. Roller radius has great effect on the spinning force	4. Punch radius has great effect on the drawing force
5. Wall thickness variations are similar to drawing	5. Same
6. It can able to produce aircraft and missile industries with require a high strength to weight ratio for components	6. It is not possible
7. High dimensional accuracy and surface finish is possible	7. Comparatively spinning it is very low
8. It can be produced work pieces with rotational symmetry of almost any shape	8. It can able to produce cylindrical shells, cups
9. To minimize the possibilities of more work piece failure	9. Comparatively spinning work piece failures are more
10. For larger components like cook pots, washing machines must be produced but tooling and machining cost is very less	10. For larger components tooling and machining cost would be very high

5. CONCLUSIONS

The conclusions are obtained from the above methodologies of sheet metal forming processes

- The tooling cost would be reduced for larger components in spinning process.
- High accuracy obtained in spinning process
- Good surface finish occurred in the products which are obtained from the spinning process compared with deep drawing
- For small products to be produced in large quantities spinning is not economical
- For small components to be produced in large quantities deep drawing is generally more because of its shorter cycle time
- The failures of components are low in spinning process and high in deep drawing
- The process are considered for producing the components are more in deep drawing than spinning operation
- Machinary and tooling set for spinning process is simple
- Machinary and tooling set for deep drawing process is not simple and it is heavy.
- The mechanical properties of raw material was increased by 2 to 2.5 times in spinning process than deep drawing.
- Drawing The usual range of the maximum darwing ratio is 1.6 to 2.3.

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AUTHOR PROFILE

Dr.R.Uday Kumar working as Assistant Professor in Department of Mechanical Engineering, Mahatma Gandhi Institute of Technology, Gandipet, Hyderabad, Andhra Pradesh. He obtained B.E in Mechanical Engineering from Andhra University, Vishakhapatnam, Andhrapradesh and M.Tech in Production Engineering from JNTUH, Hyderabad, A.P. He did his Ph.D in Mechanical Engineering in the field of Metal Forming from JNTUH, Hyderabad, A.P. He published 30 Technical papers in various international journals and conferences. He taught 12 subjects in the field of Mechanical Engineering. He published one book with LAP Lambert academic publishing, Germany. His areas of interest include Hydro forming, Sheet metal forming, Bulk Metal Forming, Finite Element Analysis, Special manufacturing processes, Stress analysis, and computational fluid dynamics. He is a reviewer and editorial board member for International journals such as IJMET, IJARET, IJPTM, IRJESTI, IJPRET, IJTE, IJMMS, IJDMT and IJIERD.