A Review on Design and Analysis of Deep Drawn Component

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Abstract- *One of the commonly used metal forming processes is deep drawing in which circular blanks are converted into a cup or shell with good surface finish. In this paper, the forming characteristics of Deep Draw Steel low carbon steel with many engineering and automotive applications are investigated by deep drawing. The forming limit diagram is a useful concept in favor of characterizing the formability of sheet metal. The present work is aimed to investigate the limiting draw ratio and the forming limit diagram during forming for the various punch strokes is examined. Product defects are often encountered in the industrial practice. Material breakage, wrinkling, shape defects due to spring back are most frequent defects in sheet metal forming operations.*

In this research, the deep drawing dies are designed by using a "computer aided designed calculating system" to save time and facilitate the design process. The computer aided design system, which was linked to drafting package ANSYS workbench to plot the deep drawing dies. A commercially available finite elements program code ANSYS structural analysis was used to perform the numerical simulation. A finite elements result is compared with experimental results.

Keywords- Metal forming process, deep drawing, Finite element

I. INTRODUCTION

Deep drawing is a manufacturing process that is used extensively in the forming of sheet metal into cup or box like structures. Pots and pans for cooking, containers, sinks, automobile parts, such as panels and gas tanks, are among a few of the items manufactured by sheet metal deep drawing. A basic deep drawing operation could be the forming of a flat sheet into a three dimensional cup, or a box. The shape of a deep drawn part is not limited to a circle or square, more complex contours are possible. However, as the complexity goes up, the manufacturing difficulties increase rapidly. It is best to design the shape of a deep drawing to be as simple as possible. For the primary sheet metal deep drawing process the part will have a flat base and straight sides. Deep drawing of sheet metal is performed with a punch and die. The punch is the desired shape of the base of the part, once drawn. The die cavity matches the punch and is a little wider to allow for its passage, as well as clearance. This setup is similar to sheet metal cutting operations. As in cutting, clearance is the lateral distance between the die edge and the punch edge. The sheet metal work piece, called a blank, is placed over the die opening. A blank holder, that surrounds the punch, applies pressure to the entire surface of the blank, (except the area under the punch), holding the sheet metal work flat against

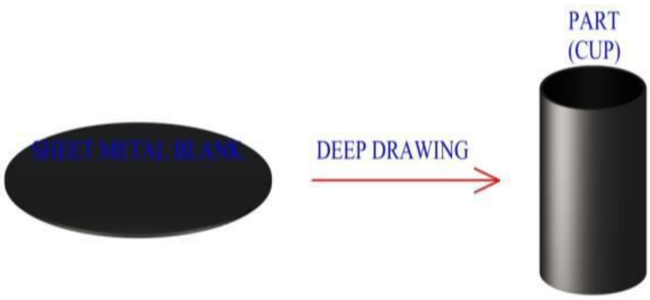

Fig. Basic diagram of deep drawn component

the die. The punch travels towards the blank. After contacting the work, the punch forces the sheet metal into the die cavity, forming its shape. Equipment for sheet metal deep drawing processes would involve a double action, one for the blank holder and one for the punch. Both mechanical and hydraulic presses are used in manufacturing industry. Typically the hydraulic press can control the blank holder and punch actions separately, but the mechanical press is faster. Punch and die materials, for the deep drawing of sheet metal, are usually tool steels and iron. However, the range of materials for punch and die can span from plastics to carbides. Parts are usually drawn at speeds of 4 to 12 inches per second. The important variables which affect the formability of sheet metal in deep drawing process can be divided into two categories: Material and friction factors; and tooling and equipment factors. With the right and proper selection of these variables, the formability of the material can be process at its optimum result and reducing the defect in deep drawing process like fracture, wrinkling and earring Sheet metal forming process is used for both serial and mass production. Their characteristics are high productivity, highly efficient use for material, easy servicing machines, the ability to employ workers with relatively less basic skills and other advantageous economic aspects. Part that made from sheet metal has many attractive Qualities: Good accuracy of dimension, adequate strength, light weight and a broad range of possible dimensions.

1.1 Forces in Deep Drawing Sheet Metal

Force used to accomplish a sheet metal deep drawing operation must be adequate enough to provide for the sheet's deformation, enact proper metal flow and overcome friction during the process. Magnitude of force must not be too high or applied incorrectly, or else tearing of the sheet metal may occur. The punch and the blank holder will exert separate forces and force analysis should be done for both.

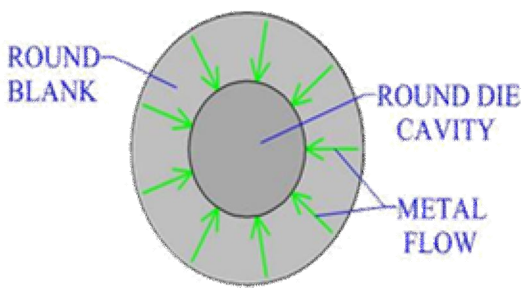

Fig. Metal Flow in Deep Drawing

Understanding the material flow during the manufacturing process is essential to understanding the forces acting on the work. Imagine placing a piece of paper flat on a round cup. This is similar to a piece of sheet metal on a round die cavity. Now, imitating the action of the punch, the paper is forced into the cup to take the cylindrical form of the cup. What happens is the paper folds or wrinkles in the process. This is not how a sheet metal work piece should act during a deep drawing operation. One reason is that metal material can flow, unlike the paper. So instead of the paper, place a piece of aluminum foil on the cup. Aluminum foil is metal but it still wrinkles when forced into the cup. The reason why aluminum foil wrinkles when forced into the cup is because of the inadequate thickness of the foil.

Fig: Example of Wrinkling

b. Earing

Earing is one of the defects which is commonly observed in deep drawing process. By definition, earing is uneven height at the edge of a drawn product, forming a series of peak and valleys along its circumference. Earing is the formation of waviness on the top of the drawn cup. The numbers of ears formed is commonly four but might also be two, six or eight, depending on thermo-mechanical processing and microstructure of the sheet.

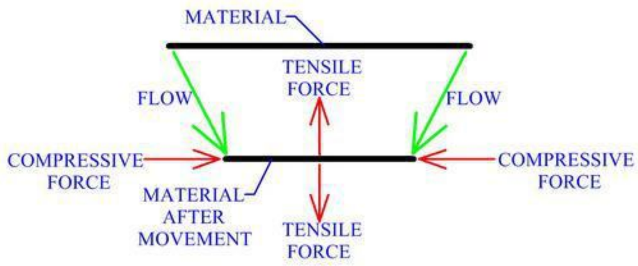

Fig. Forces Acting on Material Element in Flange

1.2 Common Defects in Deep Drawing:

In deep drawing process, there are several defects which is occurred after the deep drawing process like wrinkling, earing, excessive thinning of cup and rupture of the blank. The defects usually occur due to unsuitable or non-optimal variables in deep drawing process. Thus, in the designing the deep drawing die and run the experiment, these defects which is occur must be avoided in order to take an ideal result from the experiment.

a. Wrinkling

Wrinkling may be a serious obstacle to a successful forming process and to the assembly of parts, and may also play a significant role in the wear of tool. In order to improve productivity and the quality of products, wrinkling must be avoided. Wrinkling is a kind of buckling phenomenon that prevents from forming of the sheet. Figure shows example of wrinkling after deep drawing test. During the deep drawing process, the sheet under the blank holder is drawn into the deformation

Fig. Earing in deep drawing

c. Fracture

Fracture occurs when the sheet metal is subjected to strains exceeding the safe strain limits of the material. For ductile sheets this fracture usually occurs near the punch corner. It is because maximum forming load appears in the material in this region and also stress concentration lines are converging in this section. Once this necking exceeds beyond a certain value, fracture appears in the drawn cup. A formed cup with a fracture at the cup bottom is shown in Fig.

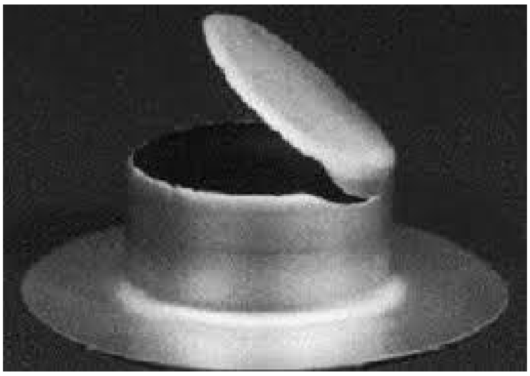

Fig. Fracture in deep drawing

II. LITERATURE REVIEW

R. Padmanabhan et al. [1] studied the effect of punch force ,blank holding force and friction conditions on thickness distribution of LPG bottles during deep drawing process. A constant blank holder force scheme induces larger deformations in the initial stages of deep drawing leading to an increased thinning at the bottom of the cup, whereas, the proposed variable blank holder force scheme and friction condition reduces the thinning of the deep drawn part. A low-constant blank holder force in the initial stage prevents necking failure between punch and die radius. The magnitude of the blank holder force at initial stages of deep drawing plays a vital role in the thickness distribution in the drawn part. When the punch force remains constant, an increasing blank holder force restrains the wrinkling tendency and enables a smooth flow of material into the die cavity.

Sandip Patil et al.[2] studied the effect of blank holding force and friction force on CRDQ steel sheet of 1 mm thickness and their effect on wrinkles and wall thickness distribution is analyzed by using Hyper Form software ,their analysis reveals that as the blank holding force increases from 2 KN to 20KN no. of wrinkles form on flange reduced, experimentation is done by using various values and from that it is conclude that friction coefficient have great influences on thickness distribution in deep drawing.

Mohan Reddy et al.[3] studied the effect of blank holding force, die corner radius and friction coefficient on the limit strain of aluminum(AA1100) in deep drawing process using a finite element method, forming limit diagram are plotted for various blank holding forces, die corner radius and friction coefficient and study conducted reveals that ,the limit strains can be obtained in simulation by taking the principal strains at ultimate tensile strength

Pradeep M Patil et.al.[4] stated that as deep drawing materials are easily shapeable; their strengths are lower compared to other materials. However, multi-stage shaped soft materials that will be ultimately used as a pressure cup require a higher strength requirement. With this purpose, although it is a negative outcome that as the drawing stage increases, the ductility of material reduces; increasing of the hardening is a profit in terms of cup yield. In above, though the force and stress is seems to be increased, the major outcome is increase in productivity. The material is stressed more below its allowable stress. The present model can be useful in conducting parametric studies on the different parameters affecting the process including die design, process and material parameters. This is beneficial in the mass production industry where time, machine and manpower are important.

Mayavan. T et al. [5] studied effect blank holding force, punch force; punch speed on the formability of low carbon deep drawing steel sheet of 0.8 mm thickness and the formability of the sheet is indicated by Liming Drawing Ratio (LDR). It is the ratio of maximum blank diameter that can be formed into cup without the flange to the diameter of the punch. The blanks of progressively increasing diameters (Do) are drawn into cups using a punch of diameter DP. The maximum diameter of the blank (D0max) just before the first defect occurs is used to find the LDR value. This LDR value determines the deep draw ability of the material Experimental Results shows that best forming characteristic were found at a punch stroke of 50 mm with LDR value of 2.2. Similar experimentation is carried out by using finite element method which shows the validation of experimental result.

Ramesh Kanttikar et al. [6] stated that Sheet metal formation during deep drawing process is simulated using Finite element software and analysis is carried out to find the load requirements with increase deep drawing forming process. The results summary is as follows. Initially the punch, sheet and fixed die are modeled as per the specifications. Later the structure is meshed with 4 noded quad elements (Plane182). The element is capable of representing the large deflection effect with plastic capabilities. Contact pairs are created between punch, sheet metal interface, die , sheet metal interface using Targe169 and Contac172 elements. The displacement load is applied and problem is executed in the nonlinear domain using material properties specified for given temperature range. Analysis has been carried out for load requirements for sheet metal formation. The results show increased load requirements with increased depth of drawing process. The stress values for radial, hoop, vanishes and contact pressure are increasing. From the finite element simulation, the region of thinning and probable regions of failure can be identified. Higher stress regions are the major regions of failures. Finite element simulation helps in avoiding prototype built up and checking for the required load calculations. The results shows punch load requirement of 218.416KN at 30mm to 256KN load for 45mm deep drawing process. So depth drawing process increases the load requirements. Further analysis is carried out to find the effect of fillet radius on the punch load and stress generation. The results shows increased value of fillet reduces the punch load requirement along with the reduction of stresses. The fillet variation of 6mm to 12 mm shows reduction of 242.412 KN of punch load to 218. 416 KN(Almost 10% reduction of punch load). Similarly stresses are reducing to the greater extent. So punch radius plays significant role on punch load requirements.

III. DESIGN PARAMETERS

1. The die design parameters like Die shoulder radius, Punch nose radius, Sheet metal thickness Radial clearance.
2. Punch forces and tool materials
3. Tool surface finish and type of lubricant used
4. Blank size and shape.
5. Punching speed, draw radii and draw ratio.
6. Draw beed height and shape.

IV. EXPERIMENTAL SETUP

Equipments

Universal testing machine equipped with pen recorder the deep drawing punch and die Set and a micrometer.

Procedure

1. Calibrate the universal-testing machine.
2. Choose the scale in the testing machine.
3. Measure the thickness and the diameter of the test specimen.
4. Measure the die throat diameter and determine R
5. Lubricate the die surface and its throat.
6. Place the specimen in position on top of the die and locate the die holder, and finally place the punch in a proper position.
7. Place the die set between the two platens of the testing machine.
8. Applied the load gradually until the cup is completely drawn.
9. Takes off the die set and get the formed cup.
10. Measure the average height of the cup

V. WORKING OPERATION

Deep drawing of sheet metal is performed with a punch and die. The punch is the desired shape of the base of the part, once drawn. The die cavity matches the punch and is a little wider to allow for its passage, as well as clearance. This setup is similar to sheet metal cutting operations.

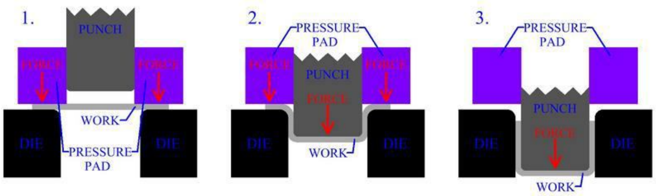

Fig. Deep drawing of sheet metal

As in cutting, clearance is the lateral distance between the die edge and the punch edge. The sheet metal work piece, called a blank, is placed over the die opening. A blank holder, that surrounds the punch, applies pressure to the entire surface of the blank, (except the area under the punch), holding the sheet metal work flat against the die. The punch travels towards the blank. After contacting the work, the punch forces the sheet metal into the die cavity, forming its shape. Equipment for sheet metal deep drawing processes would involve a double action, one for the blank holder and one for the punch. Both mechanical and hydraulic presses are used in manufacturing industry. Typically the hydraulic press can control the blank holder and punch actions separately, but the mechanical press is faster. Punch and die materials, for the deep drawing of sheet metal, are usually tool steels and iron. However, the range of materials for punch and die can span from plastics to carbides. Parts are usually drawn at speeds of 4 to 12 inches per second.

VI. CONCLUSION

A lot of research, work & study have been done by many researchers in the field of study the deep drawing or warm deep drawing of high strength, low formability materials like Al and Mg alloys. Very little amount of research work has been carried out in deep drawing or warm deep drawing of materials like stainless steel, copper, high strength low alloy steels etc, even though these materials are very extensively used in many industries like automobile, aeronautics, electronics industries and so on. The information regarding the metallurgical aspects of warm deep drawing is very much limited. In a full deep drawing process, deep drawing should be used as a basis for subsequent process.

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