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Research Article

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A Review on Deep Drawing Process

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Abstract—

Deep Drawing (DD) process is the one in which a punch forces a flat sheet metal blank into a die cavity. DD can also be described as the process which involves conversion of flat thin sheet metal blanks into parts of desired shape. Little work is available in the applications of DD processes at elevated temperatures which is going to be a very important manufacturing application in the coming decades. Deep Drawing (DD) is one of the sheet metal forming processes widely used in automobile, aerospace, electronics and allied industries to produce the hollow parts. The improvement in the deep drawing manufacturing process with latest methodologies leads to developments in the automobile and other sheet metal industries. Still today, this process of analysis and design is an art than science. Presently, the conventional deep drawing (CDD) operation is carried out at room temperature in industries. Although the deep drawing process of high strength / low formability metals has an extensive industrial application area, deep drawing at room temperature has serious difficulties because of the large amount of deformations revealed and high flow stresses of the materials. The present paper gives an overview of deep drawing process, its classification along with advantages, limitations and applications.

***Keywords**— Sheet metal work, Forming, Deep Drawing, Friction coefficient, aerospace industry*

I. INTRODUCTION

Sheet metal forming is one of the most important manufacturing processes, which is inexpensive for mass production in industries [1]. Sheet metal forming involves conversion of flat thin sheet metal blanks into parts of desired shape and size by subjecting the material to large plastic deformation. Metal forming processes 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 major influences on material flow. The bulk forming processes are rolling, forging, wire drawing and extrusion. Sheet metal forming processes like deep drawing, stretching, bending etc. are widely used to produce a large number of simple to complex components in automotive and aircraft industries, household appliances etc.

II. BASICS OF DEEP DRAWING

Deep Drawing (DD) is the sheet metal forming process which is used to produce containers from flat circular blanks. The central portion of sheet of blank is subjected to pressure applied by punch into a die opening to get a sheet metal of required shape without folding the corners. This generally requires the use of presses having a double action for blank holding force and punch force. DD can also be defined as the combined tensile and compression deformation of a sheet to form a hollow body, without intentional change in sheet thickness [2].

2.1 PRINCIPLE OF DEEP DRAWING

A flat blank of sheet metal is formed into a cylindrical cup by forcing a punch against the centre portion of a blank that rests on the die ring. The blank may be circular or rectangular, or of a more complex outline. Blank holder is loaded by a blank holder force, which is necessary to prevent wrinkling and to control the material flow into the die cavity simultaneously transferring the specific shape of the punch and the die to the blank. The material is drawn out of the blank holder-die region during the forming stage and the material is subjected to compressive and tensile stresses in this portion. The principle of deep drawing is schematically represented in Fig. 1 [3].

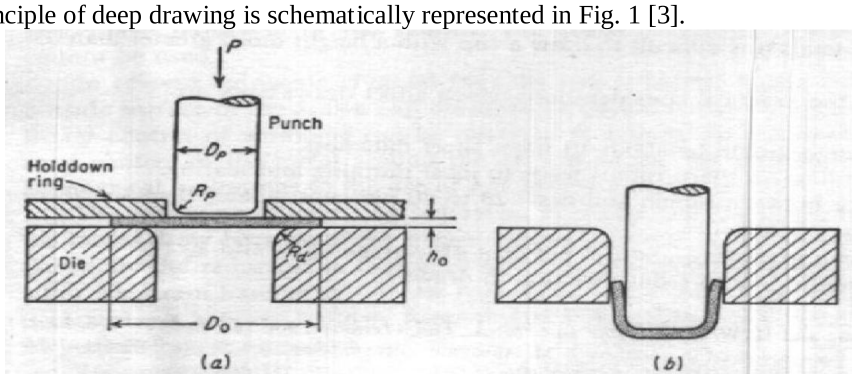

Fig. 1 Deep drawing of a cylindrical cup (a) before drawing and (b) after drawing *[3]*

2.2 COMMON DEFECTS IN DEEP DRAWING

The three major common defects which occur during DD are fracture, wrinkling and earing. 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 Fig2.

Fig. 2 Fracture in deep drawing [4]

Wrinkling occurs in the flange when compressive stresses in the circumferential direction reaches a critical point of instability. It can occur in regions where the work piece is unsupported or when the blank holding force is insufficient. Wrinkling defect is shown in Fig. 3. The wrinkling can be prevented by increasing blank holder force and by using a draw bead [5]. The draw bead bends and unbends the work piece material as it passes through the blank holder. This bending over the bead increases the radial tensile stresses and thus reduces the possibility of wrinkling.

Fig. 3 Wrinkling in deep drawing

Deep drawing of anisotropic sheets results in a drawn cup with uneven top edge i.e. some kind of ears are formed at the top as shown in Fig. 4. This defect is called earing and it is because of planar anisotropy of the blank material.

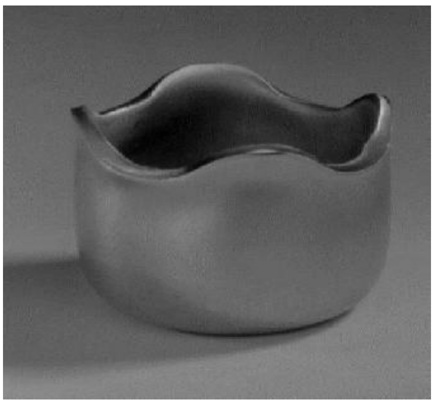

Fig. 4 Earing in deep drawing [6]

III. CLASSIFICATION OF DEEP DRAWING

The deep drawing may be broadly classified as a conventional deep drawing and a non-conventional deep drawing depending on the method of operation [7]. The detailed classification of various deep drawing processes is shown in the Figure 5.

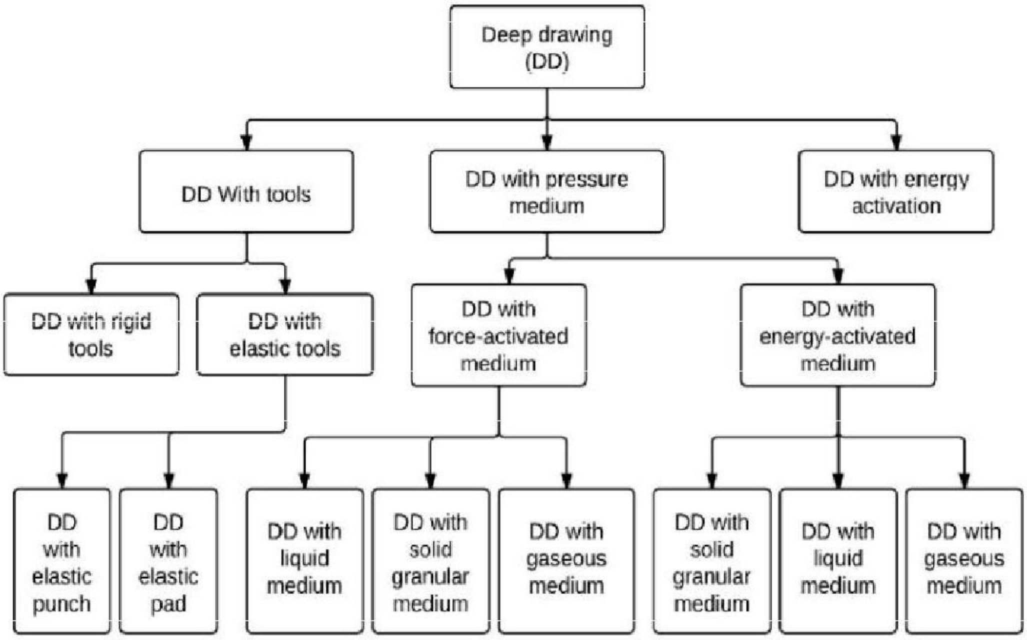

Fig. 5 Classification of deep drawing

3.1 CONVENTIONAL DEEP DRAWING

In conventional deep drawing (CDD) process, the sheet metal is formed into a cup shaped component. In this process, a flat circular sheet of metal called blank is placed over the opening in the die and then pushed through and deformed by a moving punch. As the punch moves downward, the outer annulus of the blank (flange) moves radially inward. The tendency of the flange to fold up ward (wrinkling) is restricted by the blank holder force. In CDD the majority of the deformation occurs in the flange of the cup. The metal is subjected to three different types of stress systems (as shown in Fig. 6). These stresses have influence over thickness variation in drawn cup. The primary deformation occurs in the flange of the deforming cup which undergoes radial tension and circumferential compression. Because of this, thickness increases in the flange portion. The second deformation zone is the bending around the die radius while the third deformation zone is the uni-axial stretching (plane strain) in the cup wall, which causes thinning of the metal.

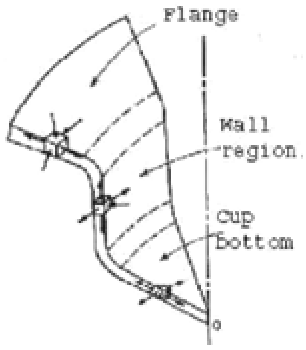

Fig. 6 Stresses and deformation in a section of a cup during deep drawing

3.1.1 PROBLEMS ENCOUNTERED IN CONVENTIONAL DEEP DRAWING

Some of the problems encountered during the conventional deep drawing operation are:

(i) Difficulty in finding the metal flow precisely.
(ii) Difficulty in setting the criteria for the stability of the metal forming process.
(iii) Complexity involved in the selection of precise process parameters and proper press tool design parameters.
(iv) Large deformation during deep drawing at room temperature causes problems in forming high strength, low formability materials like magnesium, aluminium alloys etc
(iv) Deformation induced transformation of microstructure as in the case of austenitic stainless steels.
(v) Number of tools required to produce the desired defect free component.

3.1.2 LIMITATIONS OF CONVENTIONAL DEEP DRAWING

The main limitations of conventional deep drawing are:

1. Very high limiting draw ratio cannot be obtained due to excessive thinning and fracture in the cup wall, associated with large draw ratios. For most of the common sheet materials, an LDR of more than 2.2-2.3 is extremely difficult to achieve [8].

2. Very sharp corners of the punch and the die lead to fracture.
3. High friction between the die and the sheet puts a limit on the LDR and increases the punch force required for drawing.
4. The surface finish of the component obtained usually is of low quality due to the friction between the sheet and the punch and between the die and the sheet.
5. Beyond a certain extent enhancement in formability is not possible because of inherent limitations of conventional sheet forming processes. But it was shown that higher forming limits than in conventional forming processes would be possible with the modification of the process itself [9].

3.2 NONCONVENTIONAL DEEP DRAWING

Non-conventional deep drawing is one in which other than the usual mechanical punch like hydraulic, pneumatic, gas etc., is used to provide the required force or some additional means are used along with the conventional method to improve the forming characteristics of a material. Some of the nonconventional deep drawing operations are hydro-forming (HF), hydro-mechanical forming (HMDD), warm deep drawing (WDD), super plastic forming (SPF), electromagnetic forming (EMF), incremental forming (IF) etc.

3.2.1 ADVANTAGES OF NONCONVENTIONAL DEEP DRAWING

(i) Metals can be deep drawn which, otherwise, cannot be made at room temperature due to their poor forming characteristics.
(ii) Possibility of deep drawing high strength low formability metals and alloys.
(iii) Components of very thin sheet (less than 0.5 mm) can be drawn successfully.
(iv) Lesser forming force to form the component. Reduction in number of tools required for producing the desired part and hence the reduction in production cost.
(vi) Decrease in the probability of defect formation on the product surface.

3.2.2 LIMITATIONS OF NONCONVENTIONAL DEEP DRAWING

(i) Higher capital cost of the additional equipment in some of the processes like hydro-forming, electromagnetic forming. These processes are justifiable only when the production quantities are larger.
(ii) In some processes like electromagnetic forming, gas forming, an operational safety is the primary concern.
(iii) Large operational time, as in superplastic forming etc., and hence the productivity is lower and the cost of the part is higher.
iv) Numerous process parameters need to be optimized in order to achieve a defect free component.

IV. CONCLUSION

Numerous researchers put their efforts to 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.

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