Draw Relations Derived from Mechanics of DeepDrawing Process

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Abstract. Deep drawing process is extensively used in most of the manufacturing industries for production of components used in automobile, aerospace, beverage and domestic The range varies from simple cups to large complex aerospace components. It involves major plastic deformation of the complete ductile flat blank. It may be a single stage or multistage operation depending upon the complexity of the component produced. The number of stages depends upon the nature of the material, process parameters and tool parameters.

Keywords: Deep Drawing · Drawing Ratio · LDR · Mechanics of Deep Drawing · No. of Draws

1 Introduction

Deep drawing process under sheet metal forming operations is extensively used in most of the manufacturing industries such as automobile, aerospace, beverage and domestic in order to change the shape of the geometry of the blank without variation in thickness of the blank. The range varies from simple cups to large complex aerospace components. Deep drawing operation involves major plastic deformation of the complete flat blank. This process is most suitable for ductile materials such as aluminium, copper, brass and mild steel. During the process, the tensile and compressive forces are applied to cause plasticity in the material so that the flank blank deforms into the desired shape such as circular, square, rectangular, tapered walls or curved walls depending upon the shape of the tool setup used in the deep drawing process. It may be a single stage or multistage operation depending upon the complexity of the component produced. The number of stages depends upon the nature of the material, process parameters and tool parameters.

2 Mechanics of Metal Forming in Deep Drawing

Deep drawing is the metal forming process by which a flat sheet of metal is formed into a seamless shell. During the process the material is drawn by the punch into the die and forms into a 3D shape. The blank is held by the blank holder for smooth flow in forming a cup. Wrinkling and tearing are the some of the failures in deep drawing and there are different analytical and experimental approaches in predicting and preventing theses defects.

There are different variables involved in the deep drawing process for production of quality products. They can be classified as:

- material and friction factors
- tooling and equipment factors

Important material properties such as the strain hardening coefficient (n) and normal anisotropy (R) affect the deep drawing operation. Friction and lubrication at the punch, die, and workpiece interfaces are very important to obtain a successful deep drawing process. Unlike bending operations, in which metal is plastically deformed in a relatively small area, drawing operations impose plastic deformation over large areas. Not only are large areas of the forming workpiece being deformed, but the stress states are different in different regions of the part. As a starting point, consider what appear to be three zones undergoing different types of deformation:

- the fl at portion of the blank that has not yet entered the die cavity (the fl ange)
- the portion of the blank being drawn into the die cavity (the wall)
- the zone of contact between the punch and the blank (bottom)

The radial tensile stress is due to the blank being pulled into the female die; the compressive stress, normal in the blank sheet, is due to the blank holder pressure . The punch transmits force F to the bottom of the cup, so the part of the blank that is formed into the bottom of the vessel is subjected to radial and tangential tensile stresses. From the bottom, the punch transmits the force through the walls of the cup to the flange. In this stressed state, the walls tend to elongate in the longitudinal direction . Elongation causes the cup wall to thin leading to teal of the workpiece. Fracture can also result from high longitudinal tensile stresses in the cup due to a high ratio of blank diameter to punch diameter.

The tensile hoop stress on the wall indicates that the cup may be tight on the punch because of its contraction due to the tensile stresses in the cup wall. If drawing is done without blank holder pressure , the radial tensile stresses can lead to compressive hoop stress on the flange. It is these hoop stresses that tend to cause the flange to wrinkle during drawing. Also note that, in pure drawing, the flange tends to increase in thickness as it moves toward the die cavity because its diameter is being reduced. Parts made by deep drawing usually require several successive draws. One or more annealing operations may be required to reduce work hardening by restoring the ductile grain structure.

The number of successive draws required is a function of the ratio of the part height h to the part diameter d, and is given by this formula:

$$n = \frac{h}{d} \tag{1}$$

where n is number of draws

The value of n for the cylindrical cup draw is given in Table 6.1.

Table 1. Numbers of draws (n) for a cylindrical cup draw

h/d	¡ 0.6	0.6 to 1.4	1.4 to 2.5	2.5 to 4.0	4.0 to 7.0	7.0 to 12.0
n	1	2	3	4	5	6

2.1 Deep Drawability

In deep drawing , deformation may be expressed in four ways, thus:

$$\epsilon = \frac{D - d_s}{D}; m = \frac{d_s}{D}; K = \frac{D}{d_s}; \phi = ln\frac{D}{d_s} \quad (2)$$

The relationship between these equations is:

$$\epsilon = \frac{D - d_s}{D}; = 1 - m = \frac{K - 1}{K}; \phi = \frac{e^{\phi - 1}}{e^{\phi}} \quad (3)$$

The ratio of the mean diameter ds of the drawn cup to the blank diameter D is known as the drawing ratio m, and is given by:

$$m = \frac{d_s}{D}; = 1 - \epsilon = \frac{1}{K}; = \frac{1}{e^{\phi}} \quad (4)$$

Very often, deep deformability is expressed as the reciprocal of the drawing ratio m. This value K is known as the limit of the drawing ratio:

$$K = \frac{D}{d_s}; = \frac{1}{m}; = e^{\phi} \quad (5)$$

where D = the blank diameter
d_s = the mean diameter of the drawn cup
m = the drawing ratio
K = the limit of the drawing ratio
The values of the drawing ratio for the first and succeeding operations is given by:

$$m_1 = \frac{d_s 1}{D}; m_2 = \frac{d_{s2}}{d_{s1}}; m_3 = \frac{d_{s3}}{d_{s2}}; m_n = \frac{d_{sn}}{d_{sn-1}} \quad (6)$$

The magnitude of these ratios determines the following parameters:

- the stresses and forces of the deep drawing process
- the number of successive draws
- the blank holder force
- the quality of the final drawn parts

In view of the complex interaction of factors, certain guidelines have been established for a minimum value of the drawing ratio . The relative thickness of material is the most important and may be calculated from:

$$T_r = \frac{T}{D} x100\% \tag{7}$$

As the relative thickness of the material Tr becomes greater, the drawing ratio m becomes more favorable.

Table 2. Optimal ratio m for drawing a cylindrical cup without flange

Ratio of drawing m	Relative thickness of the material $T_r = \frac{T}{D}100\%$					
	2.0–1.5	1.5–1.0	1.0–0.6	0.6–0.3	0.3–0.15	0.15 – 0.08
m1	0.48–0.50	0.50–0.53	0.53–0.55	0.55–0.58	0.58–0.60	0.60–0.63
m2	0.73–0.75	0.75–0.76	0.76–0.78	0.78–0.79	0.79–0.80	0.80–0.82
m3	0.76–0.78	0.78–0.79	0.79–0.80	0.81–0.82	0.81–0.82	0.80–0.84
m4	0.78–0.80	0.80–0.81	0.81–0.82	0.80–0.83	0.83–0.85	0.85–0.86
m5	0.80–0.82	0.82–0.84	0.84–0.85	0.85–0.86	0.86–0.87	0.87–0.88

3 Conclusions

During the deep drawing process, the tensile and compressive forces are involved and material is subjected to plasticity plasticity and deforms into the desired shape. It may be a single stage or multistage operation depending upon the complexity of the component produced. The number of stages depends upon the nature of the material, process parameters and tool parameters and needs to thoroughly analysed and selected for defect free component.

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References

1. Shukla, Anoop Kumar, Niraj Nayan, S. V. S. Murty, S. C. Sharma, Kallol Mondal, and Parameshwar Prasad Sinha. "On the Possibility of Occurrence of Anisotropy in Processing of Cu-CNT Composites by Powder Metallurgical Techniques." In Materials Science Forum, vol. 710, pp. 285-290. Trans Tech Publications, 2012.

2. Reddy, A. C. S., S. Rajesham, P. R. Reddy, T. P. Kumar, and J. Goverdhan. "An experimental study on effect of process parameters in deep drawing using Taguchi technique." International Journal of Engineering, Science and Technology 7, no. 1 (2015): 21-32.
3. Shukla, Anoop Kumar, T. Raghu, S. Rajesham, and I. Balasundar. "Analysis of significant parameters influencing formability of titanium alloy by using over all evaluation criteria and new matrix model based on Taguchi method." Transactions of the Indian Institute of Metals 67, no. 5 (2014): 721-730.
4. Reddy, AC Sekhara, S. Rajesham, P. Ravinder Reddy, Janaki Ramulu, and Anoop Kumar. "Experimental study on strain variation and thickness distribution in deep drawing of axisymmetric components." International Journal of Current Engineering and Technology Issue-2^{s}Spl (2014).
5. Reddy, A. C. S., S. Rajesham, and P. R. Reddy. "Experimental and simulation study on the warm deep drawing of AZ31 alloy." Advances in Production Engineering & Management 10, no. 3 (2015): 153.
6. Reddy, AC Sekhara, S. Rajesham, and P. Ravinder Reddy. "Evaluation of limiting drawing ratio (LDR) in deep drawing by rapid determination method." Internal Journal of Current Engineering and Technology 4, no. 2 (2014): 757-762.
7. Reddy, AC Sekhara, and S. Rajesham. "Determination of LDR in deep drawing using reduced number of blanks." Materials Today: Proceedings 5, no. 13 (2018): 27136-27141.
8. Reddy, AC Sekhara, S. Rajesham, and T. Mahender. "Experimental and Simulation Study in Deep Drawing of Circular Cups for Determination of LDR." In International Conference on Emerging Trends in Engineering (ICETE), pp. 533-541. Springer, Cham, 2020.
9. ACSReddy Anoop Kumar Shukla, G.C.M. Reddy, C.R. Samantha, Experimental evaluation of formability of sheet metals under PTFE lubricated conditions , Institution of Engineers India Journal-MC 92 (1), 5
10. Reddy, C. Bhaskar, G. Jayachandra Reddy, and C. Eswara Reddy. "Growth of electrical discharge machining and its applications–a review." Int. J. Eng. Res. Dev 4, no. 12 (2012): 13-22.