IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)
e-ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 13, Issue 2 Ver. III (Mar- Apr. 2016), PP 69-73
www.iosrjournals.org

Review Paper on Design Parameters and Forces for Cylindrical Deep Drawing Operation

Mr. Bhushan Sanjay Paysheti[1], Dr. Shekhar Yadgiri Gajjal[2]
[1]*(Mechanical design, N.B.N.Sinhagad school of Engineering affiliated to Savitribai Phule Pune University, India)*
[2]*(H.O.D. (M.E.) Mechanical design, N.B.N.Sinhagad school of Engineering affiliated to Savitribai Phule Pune University, India)*

Abstract : *For production of sheet metal parts we need various dies which will convert flat sheet metal into desired product. The traditional techniques for design of dies for sheet metal operations used in industry are experimental and expensive methods. Using analytical methods we can calculate various design parameters and forces in the tool which will reduce the time for the development of dies. The design of dies requires inputs like press data, blank size, work strokes, die faces ,loading height of component , shut height of die , methods of loading and unloading the component etc. based on this data dies are designed. The review on various design parameters and forces which are needed to be considered during the design of draw die for cylindrical cup deep drawing operation is done in this paper, which will be helpful for further design of draw die for cylindrical cup.*

Keywords: *Blank-holder, Cupping strain factor, deep drawing, Die ring, Shut height*

I. Introduction

The traditional techniques for design of dies for sheet metal operations used in industry are experimental and expensive methods. Using analytical methods we can calculate various design parameters and forces in the tool which will reduce the time for the development of dies.

Susila Candra [1] did the research on prediction of maximum variable blank holder force over the punch stroke to avoid crack formation on sheet metal during deep drawing operation and gave empirical formulae for blank holder force. A. Pourkamali Anaraki [2] conducted the study on deep drawing process with the help of Finite Element Simulation and compared the experimental results with the analytical and simulation results and given the formula for draw force. Amir Mostafapur [3] conducted study on the effect of a pulsating blankholder system for improving the formability of aluminum 1050 alloy, using this system, during each pulsating cycle, first the metal was easily flowed into the die through removing the blankholder force, and then the blankholder force applied by springs to prevent excessive metal flow and wrinkling. In this study he gave formula for variable blank holder force depending on frequency of stroke of press. Z. Marciniak [4] studied mechanics of sheet metal forming and give the analytical formulae for Limiting Drawing Ratio which relate blank size and punch size.

Vukota Boljanovic [5] conducted study on important design parameters and various forces required for deep drawing operation of sheet metal and given important empirical formulae for deep draw die design. Ivana Suchy [6] has studied industrial die design and derived various analytical formulae for cylindrical deep drawing operation which include Severity of Draw and Number of Drawing passes, Cupping Strain Factor, Blank Size of a Drawn Shell etc. These formulae play vital role in design of die. David A. Smith [7] has studied entire die design process for various operation which also include deep drawing of cylindrical cup, he has given analytical formulae for tool design , criteria for various part selection such as size, material, tolerance values etc.

1.1 Drawing operation- Drawing is a manufacturing process in which a flat piece of sheet-metal is converted into a hollow product. Such conversion can be obtained in a single step, or in a multiple steps. In the drawing process, the material is forced to follow the movement of a punch, which pulls it along, on its way through the die. The draw force given by the punch should be sufficient to overcome the elastic limit of sheet-metal and cause plastic deformation. Various forces during the drawing operation of cup (Figure 1.1) are blank holder's force, friction between the drawn shell and other components of tooling, punch force.

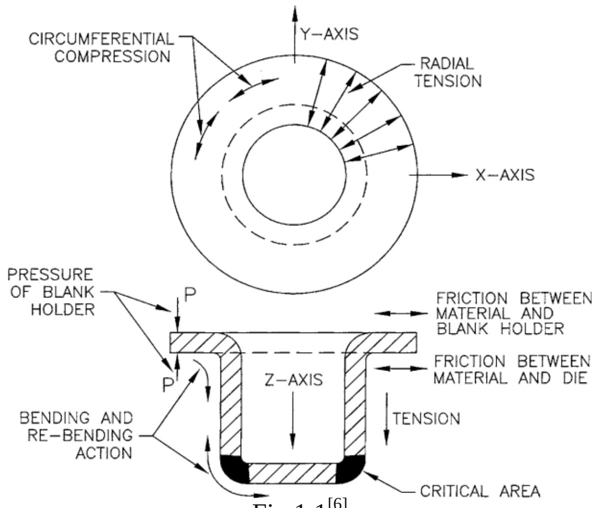
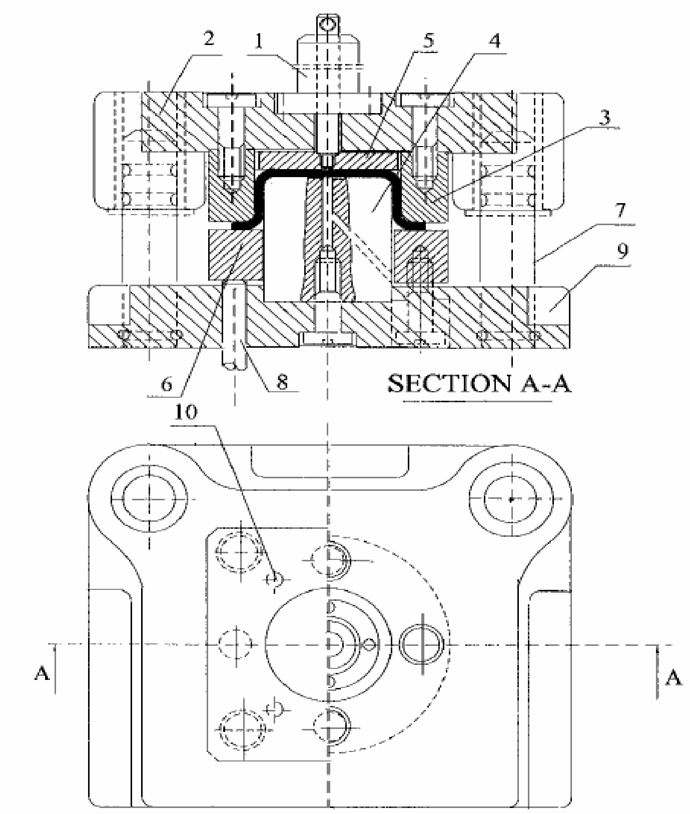


Fig 1.1[6]

1.2 Basic draw die structure



- 1-Shank
- 2-Upper shoe
- 3-Die drawing ring
- 4-Punch
- 5-Upper pad
- 6-Blank holder
- 7-Guide pin
- 8-Cushion pin
- 9-Lower shoe
- 10-Elastic stop

Fig 1.2[5]

1.3 Elements of Draw Die

1.3.1 Shank- Shank is mounted on upper shoe for some mechanical press to connect upper shoe with ram.

1.3.2 Upper shoe - It is a part of the die, fixed to ram of the press with the help of clamping screw. It moves along the ram and guided by guide pillar or wear plates mounted on lower shoe. It has cavity shape, as of the output component. The panel will flow in this cavity and take up the shape of cavity. The shape of the cavity and shape of the punch are same, only they are offsetted by the value of metal thickness. Upper shoe may be cast type or made up of steel plate based on the requirement of the design.

1.3.3 Die drawing ring – It is fixed on upper shoe with the help of screw and dowel. It has same shape of punch maintaining clearance; the clearance value depends on sheet metal thickness and material of sheet.

1.3.4 Punch - Punch has same shape of output component required from the die. It is mounted on lower shoe with help of screw and dowel. It is a rigid part. It forces sheet metal to flow in to cavity of die draw ring.

1.3.5 Upper pad **–** It is mounted on upper shoe with help of side pin or safety screw or both. It has only one degree freedom along vertical direction; other degrees of freedom are locked by guide pin or wear plate. It has pressure source such as gas spring, coil spring or elastic rubber. It holds the sheet metal before the start of operation by the force provided by pressure source.

1.3.6 Bank holder – This part of the die is mounted on lower shoe of the die. It has single degree of freedom in vertical direction. Its function is to hold the blank and provide necessary holding force for the drawing of the sheet metal. The force is provided to the blankholder by coil springs or gas springs or cushions in the press. It is moves along the upper shoe, due to force of upper shoe.

1.3.7 Guide pin – It is the guiding component used for the alignment of upper shoe and lower shoe during the operation. It is also used for the guiding of blankholder in the lower shoe.

1.3.8 Cushion pin – It is the source of force for the blankholder. The selection of cushion pin is based on force required for blankholder, travel of the blankholder and space available.

1.3.9 Lower shoe **-** It is a part of the die, fixed to bolster of the press with the help of clamping screw. Lower shoe may be made by casting or made up of steel plate based on the requirement of the design. Various elements are mounted on the lower shoe like guide pins and wear plate for upper shoe , guide pins and wear plate for blankholder, blankholder, coil springs or gas springs for blankholder, punch for drawing operation.

1.3.10 Elastic stop **–** It is a pressure source of upper pad which provides force to hold the sheet metal at proper location before the start of deformation of sheet metal, and it limits the displacement of upper pad in vertical direction.

II. Parameters And Forces For Cylindrical Deep Draw Die

2.1 Basic Terminology

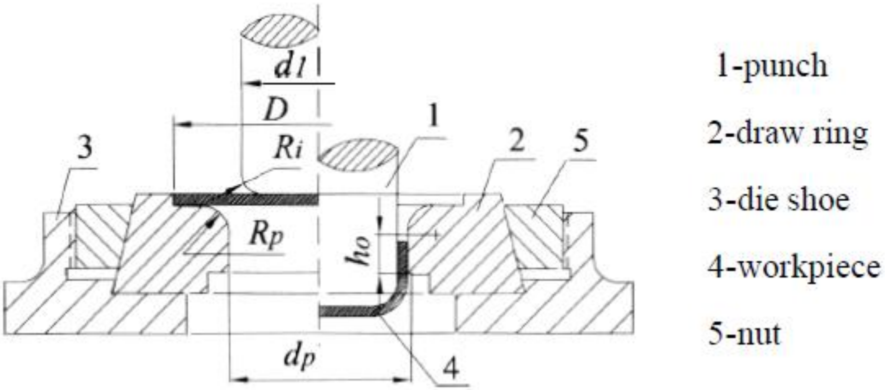


Fig 2.1[5]

Where, D =Blank diameter

d_1 = Inside work piece diameter after the first drawing operation

T = Material thickness

R_p= Draw ring

R_i= Punch radius

d_p= Outside work piece diameter after the first drawing operation

2.1.1 Radius of draw ring (R_p)

$R_p = 0.8[(D-d_1) X T]^{0.5}$…………………………………… (1)[5]

2.1.2 Height of the cylindrical part of the draw ring (h_0)

$h_0 = (3/5) X T$ …………………………………………..... (2)[5]

2.1.3 Clearance (C) - The clearance between the walls of the punch and the die is a very important parameter. The clearance value may be defined by an empirical formula depending on the kind and thickness of the material. The clearance between punch and draw ring is given by

$C = T + k (10T)^{0.5}$ ………………………………………. (3)[5]

Where:

C = clearance

T = material thickness

k = coefficient

Table 2.1[5]

Material	Coefficient k
Steel sheet	0.07
Aluminum sheet	0.02
Other metal sheet	0.04

2.2 Calculation of the Dimensions of the Punch and Die ring

When the value of the clearance (C) is known, value of the punch dimensions can be found out based on outside or the inside dimension of the final product be within a given tolerance.

2.2.1 If outer diameter of the product must be within a certain tolerance, the draw ring diameter (dp) is equal to the minimum outside diameter of the final piece, and the punch diameter is less than the draw ring diameter by 2C. The nominal draw ring diameter is:

$$dp = do - F \text{ ……………………………………… } (4)^{[5]}$$

The draw ring and punch are assigned working tolerances (t_p, t_i), given in Table 3.2, where d is the nominal diameter of the final product and T is the thickness of sheet metal.

d(mm)	tolerance	Material Thickness T (mm)									
		0.25	0.35	0.50	0.60	0.80	1.0	1.2	1.5	2.0	2.5
10 to 50	$+t_p$	0.02	0.03	0.04	0.05	0.07	0.08	0.09	0.11	0.13	0.15
	$-t_i$	0.01	0.02	0.03	0.03	0.04	0.05	0.06	0.07	0.08	0.10
51 to 200	$+t_p$	0.03	0.04	0.05	0.06	0.08	0.09	0.10	0.12	0.15	0.18
	$-t_i$	0.01	0.02	0.00	0.04	0.05	0.06	0.07	0.08	0.10	0.12
201 to 500	$+t_p$	0.03	0.04	0.05	0.06	0.08	0.10	0.12	0.14	0.17	0.20
	$-t_i$	0.01	0.02	0.03	0.04	0.06	0.07	0.08	0.09	0.12	0.14

Table 2.2[5]

The maximum draw ring diameter (d_{pmax}) is given by

$$d_{pmax} = d_p + t_p \text{ ……………………………………… } (5)^{[5]}$$

The nominal punch diameter (d_i)

$$di = d_p - 2C \text{ …………………………………… } (6)^{[5]}$$

The minimum punch diameter (d_{imin})

$$d_{imin} = d_i - t_i \text{ ………………………………………} (7)^{[5]}$$

Where:

d_p , d_i= nominal draw ring and punch diameter

d_o = nominal diameter of the outside of final piece

F = final piece’s working tolerance

C = clearance.

t_p, t_i = work tolerance of draw ring and punch

d_u = nominal diameter of the inside of the final piece

2.2.2 If the inside diameter of the final piece is within the tolerance, the punch diameter (d_i) is equal to the minimal inside diameter of the final piece, and the draw ring diameter is larger than the punch diameter for 2C

The nominal punch diameter is $d_i = d_u$

The minimal punch diameter ($d_{i,mean}$)

$$d_{i,mean} = d_i - t_i = d_u - t_i \text{ ………………………………………} (8)^{[5]}$$

The nominal draw ring diameter d_p

$$d_p = d_i + 2C = d_u + 2 \text{ …………………………………} (9)^{[5]}$$

2.2.3 The punch nose radius ($R_{i(i)}$) for deep drawing operations is given by-

$$R_{i(i)} = (d_i - d_{i-1})/2 \text{ …………………………………} (10)^{[5]}$$

Where:

$R_{i(i)}$ = punch radius i-th drawing operation,

d_i , d_{i-1} = punch diameter i-th and (i- 1) drawing operation

The punch nose radius depends on the thickness and type of work piece material. For the first drawing operation the punch nose radius is:

$$R_{i(1)} = (0.9)T \text{ for brass …………………………………} (11)^{[5]}$$

$$R_{i(1)} = (0.93)T \text{ for steel…………………………………} (12)^{[5]}$$

2.1.5 Blank Holder Pressure- The blank holder pressure can be calculated by the following formula

$$Pd_1 = (0.67)\ \{[(D/d_1)^3 - 1] + (d_1/200T)\}(UTS)\text{………………} (13)^{[5]}$$

Where

D = blank diameter

T = material thickness

d_1 = inside cup diameter after the first drawing operation

UTS = ultimate tensile stress of material

2.1.6 Blank Holder Force-The blank holder force can be calculated by the following formula:

$Fd_1 = (\pi/4)\ [D^2 - d_1^2]\ Pd_1$ …………………………….. (14)[5]

2.1.7 Draw force – draw force required for the operation is given by

$P_{draw} = A\ S_y\ n_c \ln(E_c)$…………………………..……. (15)[6]

Where-

$A = \pi\ d_1\ T$

A-area of cross section of a shell

T- Thickness of sheet metal

S_y- Yield strength of material

E- Cupping strain factor

n_c- Deformation efficiency of drawing process

The cupping strain factor E gives us the actual strain in the metal created by its elongation during the deep-drawing process. it is calculated by

$E = [(D/d_1) + 1]\ X\ 0.5$………………..……… (16)[6]

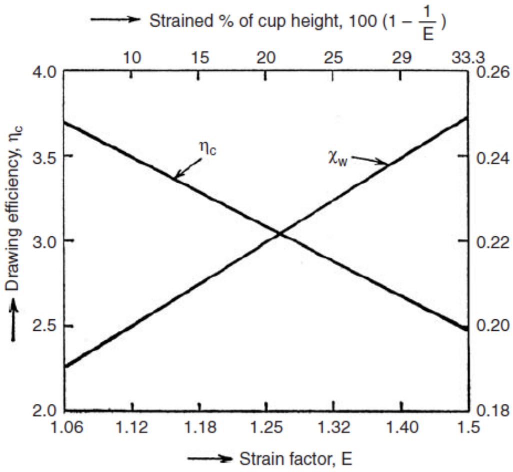


Fig 2.2[6] Deformation efficiency of drawing process (n_c)

Deformation efficiency of drawing process (n_c) is selected based on the cupping strain factor using graph from figure 2.2.

III. Conclusion

Using mathematical formulas and various design parameters at the start of design can effectively reduce the time of design over the conventional experimental methods which are practical based and very expensive. The use of values of parameters and formulas during design helps us determining exact stresses coming on various elements of die, based on these values we can select the material for elements and decide the shape of element in order provide them with sufficient strength ,and optimize the cost of tool without affecting its function.

References

[1] Susila Candrab,, I Made Londen Batana, Wajan Berataa, Agus Sigit Pramonoa, Analytical study and FEM simulation of the maximum varying blank holder force to prevent cracking on cylindrical cup deep drawing, Procedia CIRP 26 (2015) 548 – 553

[2] A. Pourkamali Anaraki, M. Shahabizadeh, and B. Babaee, Finite Element Simulation of Multi-Stage Deep Drawing Processes & Comparison with Experimental Results, World Academy of Science, Engineering and Technology 61 2012

[3] Amir Mostafapur & Sattar Ahangar & Reza Dadkhah, Numerical and experimental investigation of pulsating blankholder effect on drawing of cylindrical part of aluminum alloy in deep drawing process, Int J Adv Manuf Technol DOI 10.1007/s00170-013-5115-6

[4] Z. Marciniak , J.L. Duncan , S.J. Hu, Cylindrical deep drawing ,in ,Mechanics of Sheet Metal Forming,(Butterworth-Heinemann ,An imprint of Elsevier Science,Linacre House, Jordan Hill, Oxford OX2 8DP 225 Wildwood Avenue, Woburn, MA 01801-2041)117-127

[5] Vukota Boljanovic, SHEET METAL FORMING PROCESSES AND DIE DESIGN, (Industrial Press New York, 2004)

[6] Ivana Suchy, Handbook of die design,(Mcgraw Hill publication, United States of America,2006)

[7] David A. Smith, Die Design Handbook, (Society of manufacturing Engineers, One SME Drive. P.O. 8o\ 930. Dearborn. Michigan 48121)