Design and Analysis of Die for Macro Cup Forming

Sagar A. Bidkar[1], Ulhas B. Wankhade[2], Kamlakar G. Kuchekar[3], Dr. M. L. Kulkarni[4]
[1,2,3,4]Department of Mechanical Engineering,
MIT Academy of Engineering,
Pune, India

***Abstract* — Thefocus of present project is on "Design and Development of mini press" for macro cup forming. Deep Drawing operation will be adopted to manufacture macro cup, with dimensions in range of 10X10 (diameter=10mm and length=10mm). The used material for the work piece is Al7075 sheet having thickness in range of 0.2-0.4mm. The Press and Die performance is evaluated on the basis of the output product. The cup is checked for various considerations like dimensional accuracy, geometric accuracy, and uniform wall thickness. Also attempts are made to improve product quality by dealing with the ill effects like tearing and wrinkling, the said effects are controlled by proper design of clearance between punch and die.**

***Keywords* — Mini press, Die set, macro cup, deep drawing**

I. INTRODUCTION

In the domain of sheet metal forming, press and die have vital importance. Depending upon the capabilities of press and die the aspects like quality of formed product and its cost are controlled.

The proposed project will undertake "Designing and fabrication of mini press and the corresponding die for manufacturing Macro cup". The cups are usually produced by deep drawing operation[1].

The shape of a deep drawn part is not limited to cylinder or box, more complex shapes are also possible to produce. The manufacturing difficulties increase rapidly with shape complexity. The Deep drawing Process is performed with a punch and die. The punch geometry exhibits the replica of the object to be drawn with minor modifications. The die cavity matches the punch and is a little wider to allow for its passage as well as clearance for accommodating sheet thickness [2]. 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.

II. RESEARCH OBJECTIVE:

The Objectives of the proposed project are as follows:

1. To understand the phenomenon involved in macro cup manufacturing through deep drawing operation.
2. To carry out parametric study of dies for understanding the effect on the end product.
3. To develop design strategy for mini press and deep drawing dies.
4. To eliminate various defects like wrinkling and tearing or fracture in deep drawing process to produce cylindrical cup of desired shape and size.

However it is not easy to eliminate the defect because of the complexity in macro cup forming behavior and various other factors like die corner radius, punch corner radius, blank holding force (BHF), clearance (C) and amount of friction which affect the output product.

III. DEEP DRAWING PROCESS

Deep drawing is a sheet metal forming process where a punch is utilized to force a flat sheet metal to flow into the gap between punch and die. As a result the sheet metal blank will be formed into the desired (cup) shape and sizes like cylindrical, conical and cubical. The important variables which affect the formability of sheet metal in a Deep drawing process arefriction factor, tooling and equipment [5]. By controlling these parameters the formability of the material can be improved at its optimum result and reduce the defects in deep drawing operation

Ironing and pure bending are the two processes involved in deep drawing. In pure bending, deep drawing is carried out without reducing its thickness along its depth, whereas in Ironing thickness of blank sheet is reduced along its length[5].

IV. Details of Minin press

- **Structural description:**

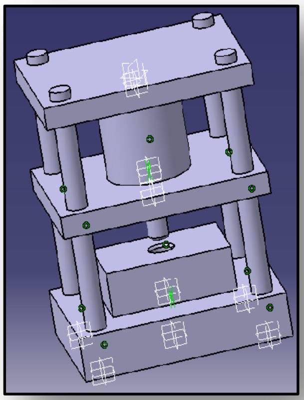

Fig. 1.1 Press Structure

The most significant elements of mini press are conventional die, punch and blank holder, whereas the other secondary part is structure. Fig.1.1 shows the details of designed mini press

The dimensional details of the cup to be produced are given below in Table I.

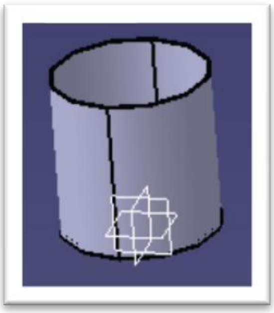

Fig. 1.2 Model of Macro Cup

Table I. Values for Macro Cup

Particulars	**Dimension (in m)**
Sheet metal thickness	0.0003
Diameter of cup	0.01
Height of cup	0.01

The equation1 is adopted for designing the die and punch [2]The opening diameter of die considering clearance between the die and punch is 0.0106. The diameter and length of punch is 0.01 and 0.026 respectively.

Material and it's Properties:

The Material used for punch and die is oil hardened nitrided steel (OHNS). Whereas the material for columns is Mild steel and base plate is made up of gray Cast iron (GCI),
The material used for blank sheet is Aluminum alloy (Al7075)

Table II. Properties for Al7075

Description	**Values**
Poisson Ration	0.33
Ultimate tensile strength (UTS)MPa	220
Yield Strength (YS)MPa	95

V. Design

- Die Corner radius (Rdc) = 4t to 10t
- Punch Corner radius (Rpc) = 3t to 4t
- Clearance (C) = 1.1t to 1.4t

The theories used for designing the work piece and the die element are given below through equation (1) to (7)[3].

Table III. Values for drawing force (F_d)

Drawing Force (Fd)	Value
for C = 1.1t	10365.7236
for C = 1.2t	10365.5845
for C = 1.3t	10365.44541
for C = 1.4t	10365.30632

Table III. Values for holding force (F_h)

Holding Force (Fh)	Value
for Rdc = 4t	1474.776355
for Rdc = 5t	1403.006464
for Rdc = 6t	1328.013375
for Rdc = 7t	1249.797086

1) Blank diameter:

Blank diameter (D_b) = $\sqrt{{d_p}^2 + 4 * d_p * h}$ (1)

$= \sqrt{0.01^2 + 4 * 0.01 * 0.01}$

= 0.02236 m

Where, d_p = Diameter of Punch

2) Limited drawing Ratio (LDR) = $\frac{D_b}{d_p}$ (2)

= 2.236

3) Reduction Ratio (%) =$1 - \frac{1}{LDR}$ (3)

= 0.5527

4) Drawing force (F_d) = $\pi * D_b * t * UTS * (\frac{d_p}{D_b} - c)$ (4)

= 10.3657 KN

5) Holding force (F_h) = $0.015 * YS * \pi * ({D_b}^2 - (D_p + 2.2t + 2R_d)^2)$ (5)

=1.4747 KN

6) Projected area of Punch (A) = $\pi * d_p * t$ (6)

$=2.1073 * 10^{-6} m^2$

7) Drawing Pressure (P) =$\frac{F_d}{A}$ (7)

VI. Analysis

- **Cause – Effects Diagrams :**

Fig. 1.3(a) and Fig.1.3 (b) shows the various defects occurring during the cup formation and their respective causes.

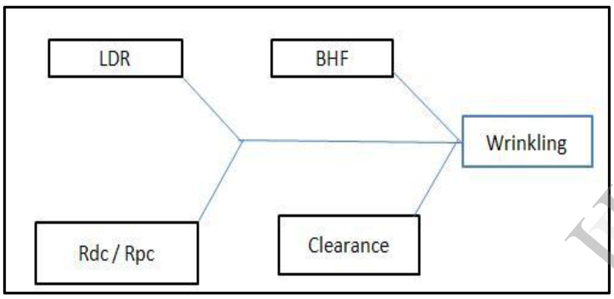

Fig.1.3(a)Causes of Wrinkling

Above Fig.1.3(a) Shows the various causes for wrinkling such as LDR, BHF, Rdc/Rpc and clearance. However the LDR, Rdc/Rpc and clearance increases the chances of wrinkling. As the higher clearance provides more space for metal to flow in the gap between the punch and die thus increasing the chances of wrinkling to occur.
High BHF is proposed to avoid wrinkling, as low BHF provides improper flow of sheet metal causing non uniform thickness of work piece.

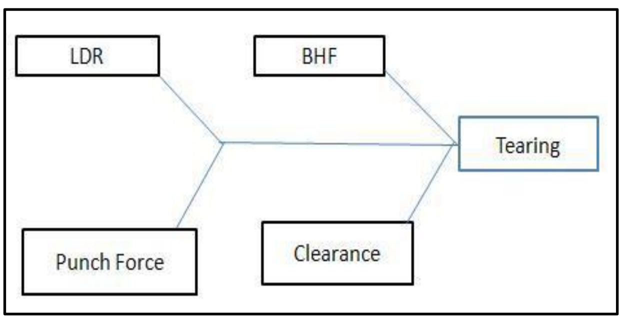

Fig.1.3(b)Causes of Tearing

Fig 1.3 (b) represents the factor responsible for tearing. If LDR is too low then there might be chances of tearing the sheet metal, because if the diameter of blank is large as compared to the punch diameter, provision for stroke length need to be large thus the chances of tearing occurs.
If the punch force is greater than the desirable value then the punch rapidly travels to form the cup causing the ill effect like tearing.

The results obtained are plotted below for Die Corner Radius (Rdc) Vs. Drawing Pressure and Die Corner Radius (Rdc) Vs. Drawing Pressure in fig 1.4(a) and 14(b) respectively.

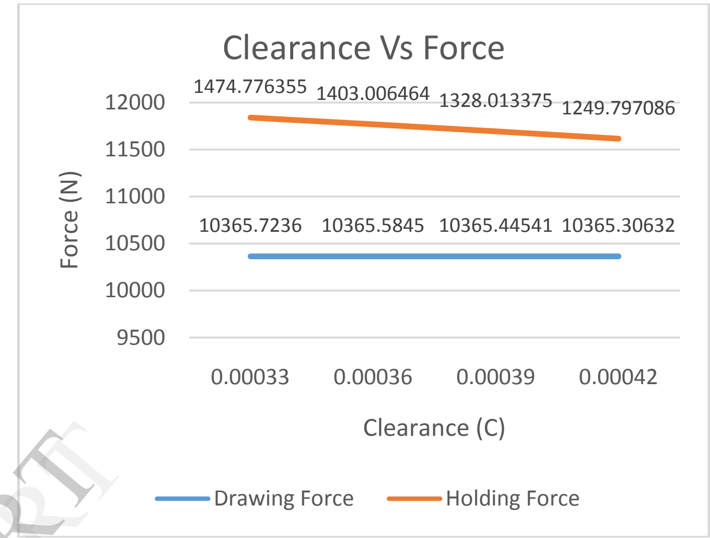

Fig 1.3. Die Corner Radius (Rdc) Vs. Drawing Pressure

From fig.1.3 it is clear that to reduce the drawing force and holding force larger clearance to e used. However as the clearance increases the tendency of wrinkling increases due o more flow of the metal between punch and die at the same travel velocity of punch, which does not provide opportunity to the metal to get spread over large area. As a result the metal get accumulated and wrinkles get formed.

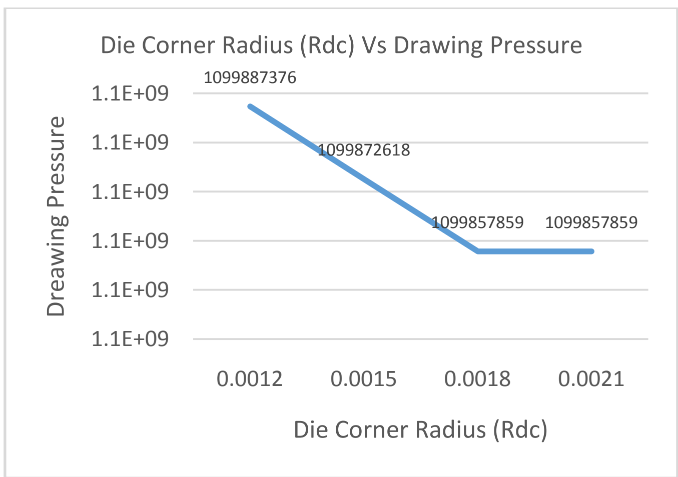

Fig 1.4. Die Corner Radius (Rdc) Vs. Drawing Pressure

The fig.1.4 indicate that the drawing pressure decreases with increase in die corner radius; as it offers least resistance to flow of metal. However the drawing pressure reduce to a limit only and there after it almost remain constant. Thus further increase in die corner radius beyond this point is not significant. Also it is noted that the increase in die corner radius help to prevent wrinkling and tearing of cup.

VII. CONCLUSION:

The macro cup forming operation posses challenges with respect to die design as the amount of material to be formed is less. At the same time the challenge of wrinkling exist as the sheet thickness is very less. Thus it is recommended to have clearance of around 0.00036m and die corner radius of 0.0012m for the case undertaken.

VIII. ACKNOWLEDGMENT

We would like to thank all the consistently supporting faculties from the department of mechanical engineering and student friends.

REFERENCES

1. Pop Alin, MihailaIoan, RaduIoan ,Blaga Florin “Parameters Influence on Wrinkling in Deep Drawing Cylindrical Cups” Nonconventional Technologies Reviews Romania, September, 2013.
2. R. Venkat Reddy, Dr. T.A. Janardhan Reddy, Dr. G.C.M. Reddy “Optimization of blank Holder force to Control Wrinkling and Fracture of Cylindrical Cups in Deep Drawing” International Journal of Engineering Trends and Technology – Volume 3 Issue 5 – 2012.
3. Ahmed Ramahi, Yahya Saleh “Design and Fabrication of a Deep Drawing Machine: Experimental Study of Drawing force Vs drawing stroke” JIMEC’7, 27-29 September 2010, Amman-Jordan.
4. H. Gharib, A.S. wifi, M. Younan, A. Nassef “Optimization of Blank Holder Force in deep Cup Drawing” Journal of Achievement in Materials and Manufacturing Engineering, Volume 18 Issue 1-2, September-October 2006
5. MetthewCoultier (10/08/2000): Sheet Metal Work, ME 353/Jesse Adams/2000.
6. Shigly, (2008), Mechanical Engineering Design, McGRAW-HILLPubl, 112, 543.
7. Cyril Donaldson, V. C. Goold, George H.LeCain, “Tool Design” Third Edition, Tata McGraw-Hill, ISBN-10:0070175314