© 2016 IJSRSET | Volume 2 | Issue 2 | Print ISSN : 2395-1990 | Online ISSN : 2394-4099
Themed Section: Engineering and Technology

Analysis of Different States of Stress in Deep Drawing Process

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ABSTRACT

A study of state of stress in deep drawing is presented by simulating a deep drawn cup. Deep drawing process is simulated using PAM STAMP 2G. In post processing, stress and strain are analysed at three different locations of a drawn cup. The material used for process is Al6061, sheet thickness is 1mm. Moreover, thickness is also analysed at the same location. The results are in agreement with the nature of stress in a deep drawing process. The simulated model can be useful in checking the possible depth of drawing for different materials.

Keywords: States of stress, Deep drawing, Simulation

I. INTRODUCTION

Manufacturing is an interesting area for a mechanical engineering as a researcher. Manufacturing is a process which converts row material into finished product. Generally it is carried out either by plastic deformation or by metal removal. When it is carried out by plastic deformation, it may be bulk metal forming or sheet metal forming.

Sheet metal forming has become very popular during the twentieth century as it is very vital process, converting a sheet metal blank into desired shape. Rolling is used to prepare sheets which are utilized as a work piece during sheet metal forming. Various processes like blanking, shearing, bending, shear spinning, shear forming, stretch forming, deep drawing, stamping, hydro forming, roll forming, etc. are applied to produce final shape from a sheet metal blank. Stainless steel and Al alloys are the most used materials for sheet metal forming. When sheet needs to be drawn for H/D ratio greater than one i.e. drawn height is more than its diameter, the process is known as deep drawing. This process is mostly applied to form cups as shown in figure 1. [1]

To study states of stress while deep drawing, a pie shaped region can be considered as shown in the figure 2. From figure 2 it is clear that the material constitutes punch region is under biaxial tensile stresses. This material wrapped around the punch and as a result, it gets thinned. While the material flowing inwards from flange have to undergo two stresses having different nature i.e. it experiences radial tensile stress and circumferential (hoop) compressive stress. Under the effect of these stresses sheet gets thickened. When this material passes through the die radius it gets bent and thinned down. Lastly the material under cup wall needs to be considered, this is obviously under simple tensile loading throughout the operation [1].

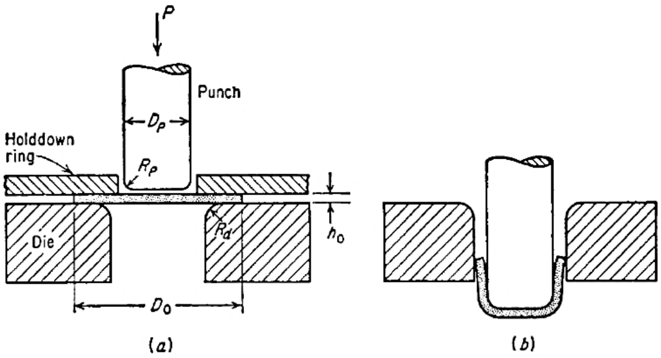

Figure 1: Deep drawing of a cylindrical cup (a) before drawing, (b) After drawing [1]

Some general design guidelines for deep drawing are as under [1]:

- Die radius should be 10 times sheet thickness.
- Punch radius should not be small to avoid thinning.

- Clearance between punch and die should be greater than 20 to 40 percent of sheet thickness.
- Die side should be lubricated to avoid friction.

In deep drawing limiting drawn ratio (LDR) is used as formability indicator. It is defined as ratio of maximum blank diameter that can be drawn without tearing to the punch diameter [2].

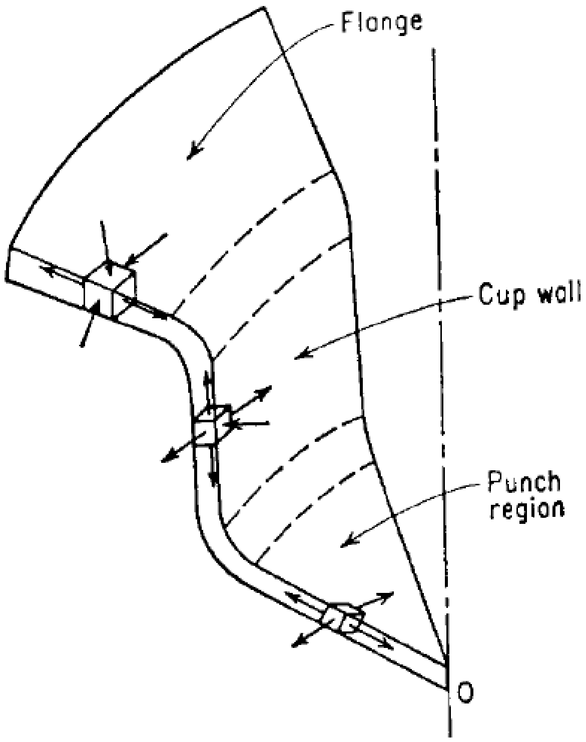

Figure 2: Stresses and deformation in a section from a drawn cup [1]

$$LDR = \left(D_s \div D_p\right) = e^{\eta} \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \quad (1.1)$$

Where, D_s = safe diameter that can be drawn,
D_p = punch diameter,
η = efficiency term to account for friction losses

II. METHODS AND MATERIAL

PAM STAMP 2G is used for carrying out the simulation of deep drawing. Iimportant aspects, which play a vital role in carrying out numerical modelling with higher accuracy and less time are mentioned below [2]:

Algorithm used for numerical modelling
Time step and increment
Elements
Material properties
Material hardening laws

Explicit algorithm is used for the process, as it is easy to analyse stress and strain at different point of time during process. Time step and increment is also explicit for calculating different properties at different phase. Elasto-plastic shell element having 4 nodes has been considered for the calculation. To consider non-associated plasticity, Hill 48 law is applied and power law is used for providing material properties. The cup has been drawn (Al6061, Holoman law) with the data mentioned in table1 [2]:

Table 1: Specifications for drawn cup

Diameter	60.3 mm
Height	104.8 mm
Blank diameter	170.1mm
Thickness	1mm
Punch velocity	1mm/sec
Punch Radius	10mm (Ten times thickness)
Calculated height	62mm
Blank holder force	27.737kN (35% of Punch force)
Clearance	0.2mm (20% of thickness)
Co-efficient of friction between Blank and Die Punch and Blank Blank holder and Blank	 0.075 0.1 0.1
1st stage LDR	1.98
Punch diameter	85.7

III. RESULTS AND DISCUSSION

Thickness contour and the locations at which various properties like stress, strain, thickness was observed are mentioned in the Figure 3.

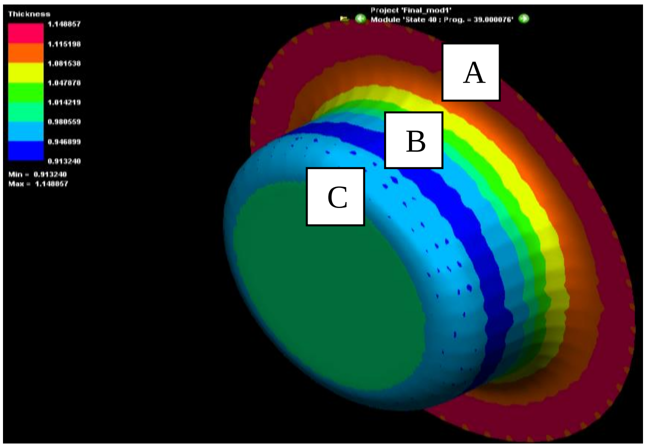

Figure 3: Locations where thickness, major and minor strain have been considered in PAM-STAMP 2G

Values of different properties have been taken by using post processor contours. Values of those properties are mentioned in Table 2.

Table 2: Results

Locat -ion	Thick-ness	Major strain	Minor strain	Major stress (MPa)	Minor Stress (MPa)
A	1.119065	0.169044	-0.283861	54.92	-326.682
B	0.954431	0.313344	-0.265656	392.240	135.074
C	0.948358	0.054180	0.000995	322.668	182.101

Results clearly confirm the states of stresses as discussed earlier. If location A is taken for example, table shows that minor strain is higher in magnitude which results in thickening. If thickness at that location is analysed than it gives the thickness of 1.11905 mm which is higher than the original thickness of the sheet.

Same way if same properties are analysed at location B, it is clear that element is under combined effect of tensile and compressive stress, but as higher tensile stress is there, it results in reduction in sheet thickness. If thickness at that location is checked, it shows 0.954431 mm which is less than the original sheet thickness.
At the end, if location C is checked than it is clear that sheet is under bi-axial strain. From the table, it is clear that least thickness at this location.

Moreover, thickness is almost same at the bottom of the formed cup. The colour of bottom of the drawn cup confirms this. As this particular region, comes under the thickness values ranging from 0.98 mm to 1.01 mm.

IV.CONCLUSION

Current work confirms the states of stresses in a drawn cup with a simulation. It is clear that stretching of side wall and thickening of flange take place while process is going on. Moreover, thickness at the bottom of cup remains same. In addition to analysis of states of stress, a simulation model for deep drawing is the outcome, which can be useful for studying effect of different process parameters.

V. REFERENCES

[1]. George E. Dieter, “Mechanical metallurgy”, 3rd edition, 1987, Mc-Graw Hill Book company (UK) Limited.
[2]. A text book, PAM-STAMP 2G 2011, User’s Guide.