Experimental and Finite Element Analysis of Deep Drawing Process of Stainless Steel, Brass & Aluminum

Nirav R. Trivedi[1] Asst. Prof. Hemanshu Joshi[2] Asst. Prof. Navnit Patel[3]
[1]M.E Student [2]Assistant Professor [3]Head of Department
[3]Department of Mechanical Engineering
[1,2,3]HJD Institute of Technical Education And Research Kera-Kutch

Abstract— Deep drawing is a manufacturing process in which sheet metal is progressively formed into a three-dimensional shape through the mechanical action of a die forming the metal around a punch. To reduce various defects in deep drawing process it is necessary to control some parameters of deep drawing process. Sheet-metal drawing is a more complex operation than cutting or bending. Number of defects can occur in a drawn product. To reduce production cost it is necessary to reduce defects accrued during deep drawing process. A punch force, material property of sheet metal, blank holding force, thickness of sheet, velocity of punch are affecting parameters in deep drawing process to regulate defects like wrinkling, tearing, earing and fracture defect. By conducting experiment in hydraulic press we know stress, strain, displacement and load. These results compare with the software for validation.

Key words: Dp, Tearing, Deform 3-D

I. INTRODUCTION

Drawing is a sheet-metal-forming operation used to make cup-shaped, box-shaped, or other complex-curved and concave parts. It is performed by placing a piece of sheet metal over a die cavity and then pushing the metal into the opening with a punch. The blank must usually be held down flat against the die by a blank holder. Common parts made by drawing include beverage cans, ammunition shells, sinks, cooking pots, and automobile body panels. [1]

It is a sheet forming operation, in which the sheet is placed over the die opening and is pushed by punch into the opening. The sheet is held flat on the die surface by using a blank holder.

A. *Stages in Deep Drawing:*

As the punch pushes the sheet, it is subjected to a bending operation. Bending of sheet occurs over the punch corner and die corner. The outside perimeter of the blank moves slightly inwards toward the cup center. In this stage, the sheet region that was bent over the die corner will be straightened in the clearance region at this stage, so that it will become cup wall region. In order to compensate the presence of sheet in cup wall, more metal will be pulled from the sheet edge, i.e., more metal moves into the die opening.

Friction between the sheet and the die, blank holder surfaces restricts the movement of sheet into the die opening. The blank holding force also influences the movement. Lubricants or drawing compounds are generally used to reduce friction forces.

Other than friction, compression occurs at the edge of the sheet. Since the perimeter is reduced, the sheet is squeezed into the die opening. Because volume remains constant, with reduction in perimeter, thickening occurs at the edge.

In thin sheets, this is replicated in the form of wrinkling. This also occurs in case of low blank holding force. If BHF very small, wrinkling occurs. If it is high, it stops the sheet from flowing properly toward the die hole, resulting in stretching and tearing of sheet.

The final cup part will have some thinning in side wall. There are also physical parameters in drawing operations. Some of these are categorized as; [2]

1) Blank material properties
2) Blank holder force
3) Punch speed
4) Die Edge Radius rd
5) Lubrication
6) Draw depth

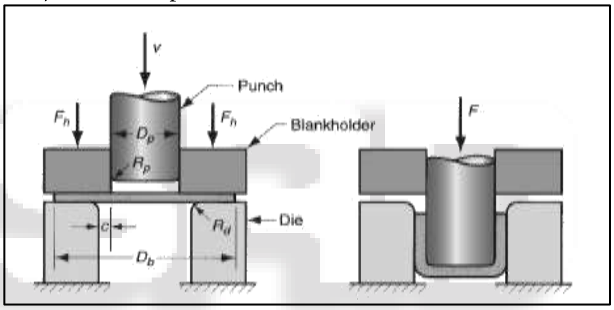

Fig. 1: Deep Drawing

c – clearance
Db – blank diameter
Dp – punch diameter
Rd – die corner radius
Rp – punch corner radius
F – drawing force
Fh – holding force

The clearance c is defined to equal to 10% more than the sheet thickness t. If the clearance between the die and the punch is less than the sheet thickness, then ironing occurs.

B. *Defects in Deep Drawing:*

Sheet-metal drawing is a more tough operation than cutting or bending, and more things can go wrong. A number of defects can occur in a drawn product, some of which we have already referred to. Following is a list of common defects, with sketches in [4] Figure 2.

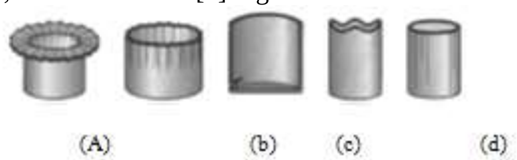

Fig. 2: Various Defects In Deep Drawing Process. [1]

1) Wrinkling in flange and cup wall: This is like ups and downs or waviness that is developed on the flange. If the flange is drawn into the die hole, it will be reserved in cup wall region.
2) Tearing: It is a crack in the cup, near the base, happening due to high tensile stresses affecting thinning and failure of the metal at this place. This can also occur due to sharp die corner.
3) Earing: This is the formation of irregularities in the upper edge of a deep drawn cup, caused by anisotropy in the sheet metal. If the material is faultlessly isotropic, ears do not form.
4) Surface scratches: Usage of rough punch, dies and poor lubrication cause scratches in a drawn cup.[1]

II. Experimental Set-up

For experiment three material Aluminum, Stainless Steel & brass are used in Table 1 types of material & its thickness are given. Velocity of punch is 1.33 mm/sec for all the experiments. To perform experimental work Hydraulic Press is used.

SPECIFICATION			
Materials	Thickness (mm)		Punch Velocity (mm/sec)
Aluminum	0.50	0.75	1.33
Stainless Steel	0.50	0.75	1.33
Brass	0.50	0.75	1.33

Table 1: Types of Material and Its Sheet Thickness

Experimental of deep drawing process is listed below;

1) Calibrate the Hydraulic Press.
2) Choose the scale.
3) Measure the thickness and the diameter of the test specimen.
4) Measure the die throat diameter.
5) Place the specimen in position on top of the die and locate the die holder and finally place the punch in a proper position.
6) Place the die set between the two platens of the testing machine.
7) Applied the load gradually until the cup is totally drawn.
8) Takes off the die set and get the formed cup.
9) Analysis of formed cup.

Fig. 3: Experimental Setup- Die, Punch, Blank Holding Plate

III. DOE

Design of experiments (DOE) is a systematic method to determine the relationship between factors affecting a process and the output of that process. In other words, it is used to find cause-and-effect relationships. This information is needed to manage process inputs in order to optimize the output. [2]

A. *DOE Steps using Minitab Software:*

1) Step 1: Open Minitab Software then go to menu bar & click on Stat -> DOE -> Factorial -> creates factorial Design. Select Full factorial Design radio button & set no of factors ton 3.
2) Step 2:
Click on Display Available Design -> Click on Design, set all 3 factors and click ok.
3) Step 3:
Enter all three factors & its values.

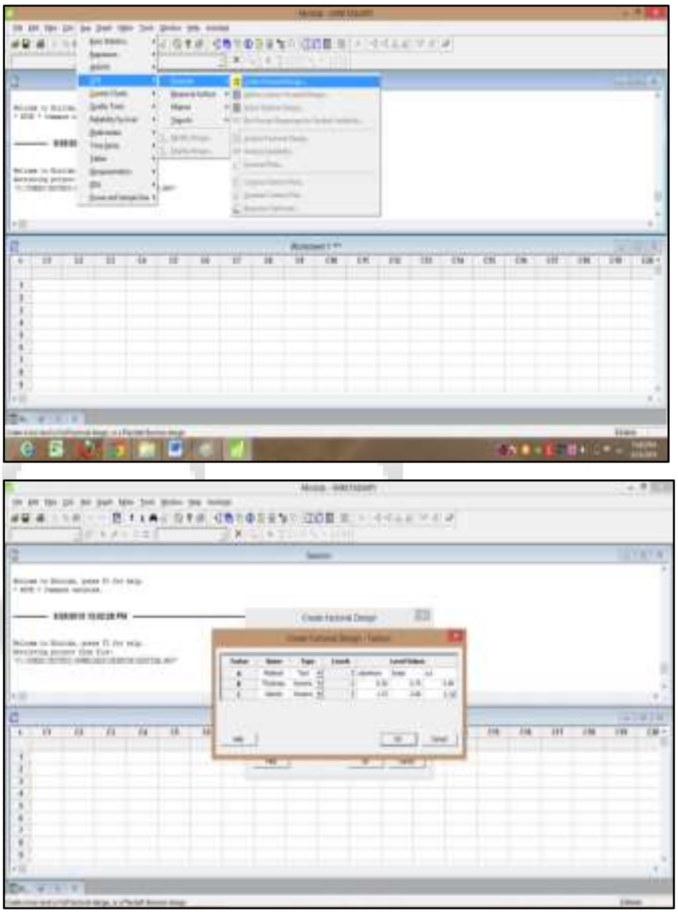

Fig. 4: Steps In Minitab Software To Find Out Total No Of Analysis

IV. Results and Discussion

A. *Experimental Results:*

Material	Thickness (mm)	Results For 10mm Deformation(N) (Experimental)
Aluminum	0.5	4.21×10^3
	0.75	5.58×10^3
Brass	0.5	14.3×10^3
	0.75	20×10^3
Steel	0.5	27.9×10^3
	0.75	49.62×10^3

Table 2: Experimental Results

Fig. 5: Brass Material

Fig. 6: Stainless Steel Material

Fig. 7: Stainless Steel Material

For simulation work Deform-3D v 6.1(service pack-1) has been used. In this software process like forming process, cogging, drilling has been conducted. Deform 3-D is mostly used for elastic material

Simulation step in Deform 3-D

1) Modeling of tools & convert it into STL file
2) Select forming command in Deform 3D
3) Choose total no. of objects
4) Import geometry of tools
5) Meshing of object
6) Position of object
7) Movement of punch
8) Total punch travel
9) Run simulation

V. SIMULATION RESULT

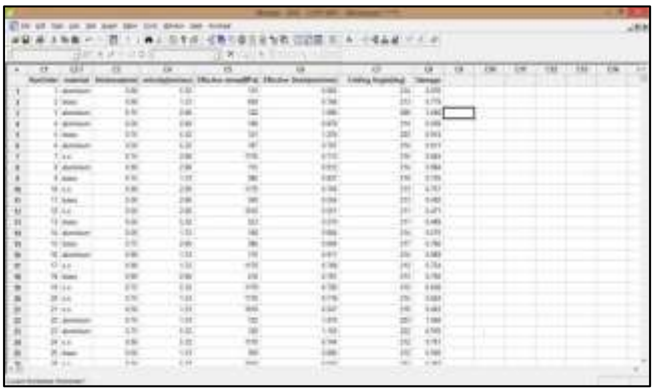

Fig. 8:

1) Optimal Parameters set for effective stress =106 MPa, Material = Aluminum, Thickness = 0.50 mm & Velocity= 2.66 mm/sec & Material = Aluminum, Thickness = 0.50 mm, Velocity = 1.33mm/sec.
2) Optimal Parameters set for effective strain = 0.547 mm/mm, Material = S.S, Thickness = 0.50 mm & Velocity= 1.33, mm/sec.
3) Optimal Parameters set for Folding angel = 206 deg. Material = Aluminum, Thickness = 0.75 mm & Velocity= 2.66, mm/sec.
4) Optimal Parameters set for Damage = 0.463, Material = S.S, Thickness = 0.50 mm & Velocity= 1.33, mm/sec.

VI. CONCLUSION

1) From the experimental results it to be analyzed that the load on aluminum material is minimum compare to the same thickness of brass and stainless steel sheet material.
2) For the 10mm deformation of cup value of load is found 21.8KN.it means the having ability to sustain the load up to 21.8 KN for 0.5mm thick plate. So from this we can conclude that the brass material having cracking point within the value of 21.8 KN load according to theory of stress strain diagram of ductile material.
3) For the 10mm deformation of cup value of load is found 30KN .it means the having ability to sustain the load up to 30 KN for 0.5mm thick plate. So from this we can conclude that the stainless steel material having cracking point within the value of 30 KN load according to theory of stress strain diagram of ductile material.
4) For the 10mm deformation of cup value of load is found 52.7KN.it means the having ability to sustain the load up to 52.7 KN for 0.5mm thick plate. So from this we can conclude that the stainless steel material having cracking point within the value of 52.7 KN load according to theory of stress strain diagram of ductile material.
5) It is observed that the damage is higher in the region of punch corner radius. Effective stress is higher on the punch radius and wall of cup. Effective strain value is more at the wall region. Folding angle is more at the punch corner radius and wall of the cup.

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REFERENCES

[1] Mikell P. Groover; ed "Fundamentals Of Modern Manufacturing"; Materials,Processes,andSystems; 4th edition; John Wiley & Sons, Inc; 2010; ISBN 978-0470-467002.
[2] Fundamental concepts of metal forming technology, R. Chandramouli Associate Dean-Research SASTRA University, Thanjavur-613401.
[3] www.isixsigma.com/tools-templates/design-of-experiments-doe/design-experiments-%E2%90%93-primer/