Experimental and Finite Element Analysis of Forming Process of Sheet Metal

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Abstract- *Drawing is a process of producing cups, shells, boxes and similar articles from metal blank. There are many process parameters, which may cause this failure such as Punch speed, Punch radius, Blank holding force, Friction, etc. Fluid assisted blank holding system we can overcome these effects or can reduce the effect of these process parameters on deep drawing process. By Experiment, we can study the thickness distribution, effect of blank holding force, Wrinkling, Cracks etc.*

Modern optical measuring methods based on digital image processing providing full-field information of 3D surface geometry, strain, and thickness reduction distributions of formed sheet metal parts (ARGUS). These optical systems have become important tools in industrial tool making and sheet metal forming processes in the last years and together with the simulation of forming, they have significant potential for quality improvement and optimization of development time for products and production.

Keywords- Forming, Simulation, Optical measurement, Strain analysis, ARGUS, PAM-STAMP (2G), GRA.

I. INTRODUCTION

Deep Drawing is one of the extensively used sheet metal forming processes in the industries to have mass production of cup shaped components in very short time. Deep drawing is the sheet metal forming process in which forming is done under compressive and tensile loads, where a sheet metal blank is transformed into a hollow cup , or a hollow cup is transformed into a smaller parts of similar dimensions without any alteration of sheet thickness. By using single draw deep drawing technique it is possible to produce a drawn part from a blank with a single working stroke of press.

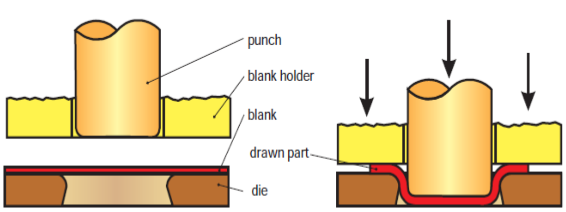


Fig. 1.1 Single Drawing with Blank Holder

Deep drawing process is frequently used in packaging industry, the automotive industry and house hold appliances industry. In deep drawing process blank is usually constrained by a blank holder, is forced into or through the die by means of punch to form the final shape of components .Circular cup drawing process is the most basic process among the deep drawing process.

Mechanics of Deep Drawing: In order to understand more clearly what happened to blank as it is being formed; it is divided into three sections as shown in fig 1.2 (i.e. x, y, and z). The material in section x will form the base of the cup which is in contact with the face of punch. Material stretches and slides over the surface of the punch. Section y represents the cup bottom radius, which has undergone bending around the die radius first, then unbending and then bending around the punch radius in opposite direction. At last the material in section z forms the sidewalls of the cup and flange. It has undergone the bending around the die radius and then unbending as it is drawn to become the sidewall.

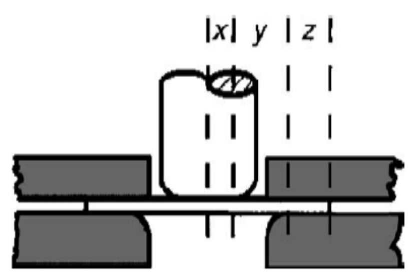
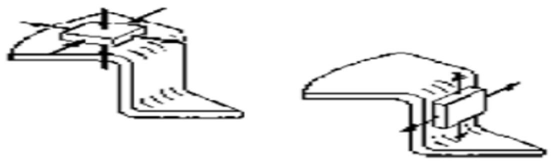


Fig. 1.2 Mechanics Deep Drawing

During a deep drawing operation, the work piece is subjected to the types of stress seen in Fig. 1.3. There is a radial stress on element A in Fig. 1.3 due to the blank being pulled into the die cavity and there is also a compressive stress normal to the element which is due to the blank-holder pressure. The radial tensile stresses lead to compressive hoop stresses because of the reduction in the circumferential direction.



(A) (B)

Fig. 1.3 Work piece Stresses during Drawing

The flange of the blank attempts to wrinkle because of this hoop stress; however, the blank-holder should prevent this from happening As seen in element B in Fig. 1.3 the wall of the cup is primarily experiencing a longitudinal tensile stress, as the punch transmits the drawing force through the walls of the cup and through the flange as it is drawn into the die cavity. There is also a tensile hoop stress caused by the cup being held tightly over the punch. The punch force is limited to the maximum tensile load that can be carried by the wall of the cup and this in turn limits the depth of flange that can be drawn.

II. LITERATURE SARVEY

Mark Colgan, John Monaghan[1] [2003]: investigated deep drawing process to determine the most important factors influencing a drawing process, utilizing the help of a design of experiments and statistical analysis. The parameters varied include the punch and die radii, the punch velocity, clamping force, and friction and draw depth. It seems that the punch/die radii have the greatest effect on the thickness of the deformed mild steel cups compared to blank-holder force or friction. The smaller is the punch/die radii, the greater is the punch force and shorter is the final draw. If the blank-holder force is not kept within the upper and lower limit of reasonable range it does have a significant effect on depth of draw, with the punch tearing through the bottom of the cup if the force is too high and if too low wrinkling of the flange area occurs.

Chandra Pal Singh, Geeta Agnihotri[2] [2015]: studied different research papers and they reviewed that deep drawing process has been an important manufacturing process to produce automotive parts of good strength and light weight. There are many process parameters and other factors that affect product quality produced by deep drawing. This paper is highlighting recent research work and results in deep drawing. Deep-drawing operations are performed to produce a light weight, high strength, low density, and corrosion resistible product. These requirements will increase tendency of wrinkling and other failure defects in the product. Parameters like as blank-holder pressure, punch radius, die radius, material properties, and coefficient of friction affect deep drawing process. So a great knowledge of process is required to produce product with minimum defects. This review paper has given the attention to gather recent development and research work in the area of deep drawing.

S. Rajesham, P. R. Reddy , T. P. Kumar, J. Goverdhan[3] [2015]: studied that The effects of various deep drawing process parameters were determined by experimental study with the use of Taguchi fractional factorial design and analysis of variance for AA6111 Aluminum alloy. The optimum process parameters were determined based on their influence on the thickness variation at different regions of the blank material. Three important process parameters i.e., punch nose radius, die shoulder radius and blank holder force were investigated in this study. Plan of experiments based on Taguchi’s technique were used for acquiring the data. An orthogonal array, the signal to noise ratio and the analysis of variance were employed to investigate the deep draw ability characteristics. Influence on thickness due to variation of these parameters was individually evaluated in terms of percentage. The results showed that the blank holder force (56.98%) was the most significant parameter followed by punch nose radius (30.12%) and the least influence (12.90%) was with die profile radius.

S. Yossifon and J. Tirosh[4] [1992]: studied that: The feasibility of replacing the rigid mechanical blank holder in the conventional deep drawing process with a soft’ hydrostatic fluid pressure is examined. The recommended fluid pressure range (the ‘working zone’) which guarantees a sound product in different circumstances is presented. The locus curve, for possible failure by wrinkling of the flange and the locus curve for possible ductile rupture along the wall provide the lower and the upper limits respectively of the ‘working zone’. These loci are found by a systematic series of deep drawing tests with different constant fluid pressure blank holders for three kinds of materials (copper, aluminum and stainless steel) at various thicknesses and friction conditions. The influence of the friction coefficient, the drawing ratio and the work piece wall thickness on the blank holder fluid pressure needed to suppress flange wrinkling becomes evident experimentally.

They found that, the Fluid Assisted Blank holding process seems to work satisfactorily within certain fluid pressure limits. The higher the drawing ratio the less fluid pressure is needed to suppress wrinkling

S. Yossifon, J. Tirosh[5] [1985]: Studied that it is intended to explain the experimental fact that relatively low fluid pressure when applied to the flange area can suppress buckling. The analysis is based on the approximate 'energy method' with the inclusion of the work against the fluid. The attention is focused on the initiation of the deep drawing process, where buckling is most susceptible. A special apparatus which enables the replacement of a rigid blank-holder by a lateral fluid pressure was used for testing. A general solution to the critical pressure, above which the deep drawing can be terminated without buckling, is provided. The prediction of the critical pressure and the number of the associated buckling 'waves' (wrinkles) agree very well with the experiments. The pertinent geometrical and material variables (as blank thickness, drawing ratio, Young modulus, yield strength, etc.) are grouped in non-dimensional form and plotted for various parameters to provide solution.

Wieslaw Frqcz, Feliks Stachowicz, Tomasz Pieja[6] [2013]: studied the use of GOM (ARGUS) photogrammetric technique for determining the real values of the analyzed draw piece strains and developing real Forming Limit Curve and comparing them with limit strain values resulting from the FLC. They had prepared a draw piece of outer diameter of 180 mm of steel AMS 5512. The draw piece was forms using a hydraulic Diefenbaker press type of 260T. The upper blank holder uses different blank holding pressures such as 2 MPa, 30 MPa, and 50 MPa, during the whole process they kept only die stationary.

III. EXPERIMENTAL SETUP

Experimental data for deep drawing process is collected from previous study. In respective study punch, force and blank holding pressure are selected as input parameters with specific range and 3 levels. Design of experimentation technique used is full factorial method. By full factorial method total 7 base runs and for better accuracy 3 replicates were taken, hence total 21 runs are there.

Table1.1 Mechanical properties of Al alloy 6180

Sr. No.	Properties	Values
1	Specific Gravity	2705 (kg/m3)
2	Poisson's Ratio	0.34
3	Young's Modulus [E]	69 (GPa)
4	Elongation	12 (Min) (%)
5	Tensile Strength	183(MPa)
6	Proof Stress	85 (Min) (Mpa)
7	Melting Point	650(0C)

Table1.2 Mechanical properties of MS IS513

Sr. No.	Properties	Values
1	Specific Gravity	7800 (kg/m3)
2	Poisson's Ratio	0.29
3	Young's Modulus [E]	210 (GPa)
4	Elongation	23 (Min) (%)
5	Tensile Strength	350 (N/mm^2)
6	Melting Point	1530 (0C)

Input Parameters:-

1. Punch Force (Ton)
2. Blank Holding Pressure (Bar)

Responses to be measure:-

1. Surface Roughness (μm)
2. Thickness of cup (mm)

Input component specification:

1. Blank diameter:-110mm
2. Draw force :-4 T
3. Blank Holding Force:-1T

Table1.3Experimental Results for Aluminium

Std Order	Run Order	Pt Type	Blocks	Punch Force (Ton)	B.H.P (bar)	Major Strain (%)	Minor Strain (%)	Thickness Reduction (%)
2	1	1	1	4	6	41.8167	-16.4023	14.215
27	2	1	1	8	8	46.8401	-19.5436	18.3651
23	3	1	1	6	6	43.8968	-16.02545	16.9586
8	4	1	1	8	6	45.7426	-19.3251	17.01258
15	5	1	1	6	8	44.8904	-19.5012	15.0236
10	6	1	1	4	4	41.3200	-14.2417	13.2462
7	7	1	1	8	4	44.3110	-16.06413	15.5489
4	8	1	1	6	4	42.7732	-15.5421	14.421
21	9	1	1	4	8	43.2190	-17.5671	14.867425

Table1.4Experimental Results for Mild Steel

Std Order	Run Order	Pt Type	Blocks	Punch Force (Ton)	B.H.P (bar)	Major Strain (%)	Minor Strain (%)	Thickness Reduction (%)
14	1	1	1	14	10	54.1465	-18.5243	18.4682
7	2	1	1	16	8	54.6682	-18.241	17.7852
1	3	1	1	12	8	49.2358	-15.4928	15.0463
20	4	1	1	12	10	52.6845	-17.0652	17.0126
22	5	1	1	14	8	52.9817	-17.2365	17.5268
18	6	1	1	16	12	56.5423	-20.0143	20.0012
3	7	1	1	12	12	54.0135	-16.5148	15.54682
8	8	1	1	16	10	56.4236	-19.0256	19.5621
24	9	1	1	14	12	56.0013	-19.5472	18.9872

Table1.5Simulated Results for Aluminium

Sr. No	Punch Force	B.H.P	Major Strain (%)	Minor Strain (%)	Thickness Reduction (%)
1	4	6	39.523	-14.562	13.3657
2	8	8	45.0028	-17.004	17.5584
3	6	6	41.897	-14.958	15.9852
4	8	6	43.5685	-17.368	16.0023
5	6	8	42.8968	-17.582	13.8925
6	4	4	39.7854	-12.785	12.854
7	8	4	41.5876	-14.658	14.5682
8	6	4	40.8276	-14.254	13.8765
9	4	8	40.2358	-15.81	13.4528

Table1.6 Simulated Results for Mild Steel

Sr. No	Punch Force	B.H.P	Major Strain (%)	Minor Strain (%)	Thickness Reduction (%)
1	14	10	50.2842	-17.285	16.5402
2	16	8	50.7868	-17.021	16.3724
3	12	8	46.4928	-14.758	14.8203
4	12	10	48.0463	-16.236	13.8928
5	14	8	49.5872	-16.654	13.8962
6	16	12	52.5864	-18.862	19.7851
7	12	12	50.0026	-15.485	15.764
8	16	10	46.9768	-14.876	15.2352
9	14	12	51.5823	-18.235	17.9823

Table1.7 Comparison between Experimental and Simulated Results (Al)

						Experimental Results			Simulated Results		
Std Order	Run Order	Pt Type	Blocks	Punch Force (Ton)	B.H.P (bar)	Major Strain (%)	Minor Strain (%)	Thickness Reduction (%)	Major Strain (%)	Minor Strain (%)	Thickness Reduction (%)
2	1	1	1	4	6	41.8167	-16.402	14.215	39.9823	-14.562	13.3657
27	2	1	1	8	8	46.8401	-19.544	18.3651	45.0028	-17.004	17.5584
23	3	1	1	6	6	43.8968	-16.025	16.9586	41.897	-14.958	15.9852
8	4	1	1	8	6	45.7426	-19.325	17.01258	43.5685	-17.368	16.0023
15	5	1	1	6	8	44.8904	-19.501	15.0236	42.8968	-17.582	13.8925
10	6	1	1	4	4	41.32	-14.242	13.2462	39.7854	-12.785	12.854
7	7	1	1	8	4	44.311	-16.064	15.5489	41.5876	-14.658	14.5682
4	8	1	1	6	4	42.7732	-15.542	14.421	40.8276	-14.254	13.8765
21	9	1	1	4	8	43.219	-17.567	14.86742	40.2358	-15.81	13.4528
Average % Error in Experimental and simulated values											
Major Strain	Minor Strain	Thickness Reduction									
4.78%	9.79%	5.79%									

Table1.8 Comparison between Experimental and Simulated Results (M.S)

						Experimental Results			Simulated Results		
Std Order	Run Order	Pt Type	Blocks	Punch Force (Ton)	B.H.P (bar)	Major Strain (%)	Minor Strain (%)	Thickness Reduction (%)	Major Strain (%)	Minor Strain (%)	Thickness Reduction (%)
14	1	1	1	14	10	54.1465	-18.5243	18.4682	50.2842	-17.285	16.5402
7	2	1	1	16	8	54.6682	-18.241	17.7852	50.7868	-17.0206	16.3724
1	3	1	1	12	8	49.2358	-15.4928	15.0463	46.4928	-14.7583	14.8203
20	4	1	1	12	10	52.6845	-17.0652	17.0126	48.0463	-16.2362	13.8928
22	5	1	1	14	8	52.9817	-17.2365	17.5268	49.5872	-16.6542	13.8962
18	6	1	1	16	12	56.5423	-20.0143	20.0012	52.5864	-18.862	19.7851
3	7	1	1	12	12	54.0135	-16.5148	15.5468	50.0026	-15.4852	15.764
8	8	1	1	16	10	56.4236	-19.0256	19.5621	46.9768	-14.8764	15.2352
24	9	1	1	14	12	56.0013	-19.5472	18.9872	51.5823	-18.2352	17.9823
Average % Deviation in Experimental and Simulated values											
Major Strain	Minor Strain	Thickness Reduction									
8.91%	7.50%	9.25%									

Percentage deviation obtained between experimental and simulated values is below 10% for all the responses for both materials. Hence validation of experimentation by simulation tool is achieved.

IV. CONCLUSION

Experimentation of Deep Drawing Process is done by taking punch force and blank holding pressure as input parameter. Following Conclusions can be drawn from experimental analysis and simulation.

1. As punch force increases the strain and thickness reduction increases.
2. Strain and thickness reduction are observed uniformly distributed.
3. Strain and thickness reduction values obtained by ARGUS analysis are in good agreement with the simulated results obtained from PAM-STAMP.
4. Both ARGUS system and PAM-STAMP is very user friendly to analyses forming processes.

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