Simulation Study of Effect of Various Parameters and Thickness Distribution in Deep Drawing of AISI 304 Stainless Steel Using AFDEX Software

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Abstract — In sheet metal, drawing is a process of forming flat sheet metal into hollow shapes by means of a punch that causes the metal to flow into the die cavity. This project aims to study the effect of various parameters on the deep drawing process. The project also aims to study the effect of these parameters on the thickness distribution in the final drawn cup. The material used for this study is AISI 304 stainless steel. AISI 304 is a widely-used austenitic chromium-nickel stainless steel. It has excellent drawing properties and very good formability. Modeling of workpieces and dies is carried out in SolidEdge V19. Simulation is carried out in AFDEX simulation software. The actual FEM-based calculation is performed by the simulation engine or solver. Based on the input data, necessary formulations are initiated by the software, and the required calculations are performed sequentially. A total of 15 simulations were performed in the AFDEX simulation software. In this study, three different cases are studied and in each case 5 simulations were performed. Variable parameters are binder holding force, die corner radius, and punch velocity. Whereas, co-efficient of friction and initial temperature is kept constant. Results were tabulated and analyzed for minimum damage value. Graphs were plotted to analyze the overall thickness distribution of the final drawn component.

Keywords: Solid Edge V19, AFDEX, AISI 304, BHF, Die corner Radius, Punch velocity and, Thickness Distribution

I. Introduction

Deep drawing is a manufacturing process that is used extensively in the forming of sheet metal into cup or box like structures. Pots and pans for cooking, containers, sinks, automobile parts, such as panels and gas tanks, are among a few of the items manufactured by sheet metal deep drawing. In sheet metal, drawing is a process of forming flat sheet metal into hollow shapes by means of a punch that causes the metal to flow into the die cavity. If the depth is one or more times the diameter, the process is called deep drawing.

Deep drawing of sheet metal is performed with a punch and die. The punch is the desired shape of the base of the part, once drawn. The die cavity matches the punch and is a little wider to allow for its passage, as well as clearance. This setup is similar to sheet metal cutting operati3ons. As in cutting, clearance is the lateral distance between the die edge and the punch edge. 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.

It is best to design the shape of a deep drawing to be as simple as possible. For the primary sheet metal deep drawing process the part will have a flat base.

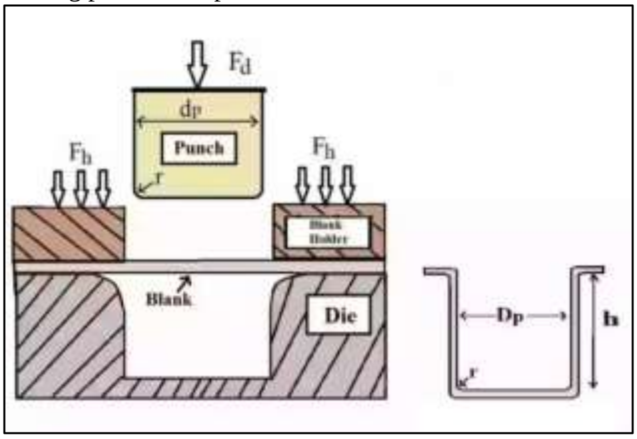

Fig. 1: Deep Drawing Process

II. Literature survey

Lade Jayahari, Banoth Balunaik, Amit Kumar Gupta, Swadesh Kumar Singh [1] Finite element Simulation studies of AISI 304 for deep drawing at various temperatures (2014). In this paper the work is aimed to investigate the formability analysis of austenitic stainless steel 304 at various temperatures under warm conditions. Limiting draw ratio and thickness distribution of deep drawn cups at i.e. room temperature and 1500C are calculated and these are the indicators of formability for any material. The experimental results shows that at room temperature the limiting draw ratio for 1mm thick sheet Austenitic stainless steel 304 is 2.1 and at 1500C for 1mm thick sheet the limiting drawing ratio is 2.5, there is any further improvement in LDR at higher temperatures.

Yogesh S. Khairnar, Dhiraj Deshmukh, Kranti Dhembre, Ganesh Sawant, Amol Bhosale. [2] Review on Optimization of process parameter in square shaped components in deep drawing process (2018). In this review paper importance is given to gather the recent research work and the effect of process parameter on the sheet metal component .There are many process parameters like that blank holding force, die radius, friction, punch speed, and other factors that affect on product quality produced by deep drawing process. In square shape of component major failures are occurs due to stress concentration at the square shape sharp edges of die and punch. Therefore is important to optimize the process parameters to avoid stressconcentration. For the ooptimization several tools have been used by researcher like ANOVA, FEA, Taguchi, etc. In this review paper major focus is to review for square shape deep drawing component.

Prof. A C Sekhara Reddy, Dr. S. Rajesham, Dr. P. Ravinder Reddy[3] Experimental Study on Strain Variation and Thickness Distribution in Deep Drawing of Axisymmetric Components (2013). Deep drawing process is an important sheet metal forming in which flat sheet metal had been forced through the die in association with the forward punch force and opposing blankholder force. As the blank passes through the tool set converts 2D bank into 3D cup form. The process of achieving the required diameter of the cup can be produced in single stage or multistage operation. In this study, experimental study had been conducted on single stage deep drawing process for assessment of radial strain, circumferential strain and thickness variation in aluminum alloyAA6061. Cylindrical cup deep drawing experimental tests were performed with blank of 350 mm diameter of 0.953mm thickness sheet. It has been found that deeper cups were produced by selecting the optimum design parameters and the results are in good agreement with simulation results found form literature.

Lucian Lazarescu, Ioan Nicodim, and Dorel Banabic[4] Evaluation of drawing force and thickness distribution in the deep-drawing process with variable blank-holding (2015). In the deep drawing process, the blank-holding force (BHF) is an important process parameter affecting the energy consumption and the successful production of parts. In the present work, both experiments and finite element simulations have been conducted to investigate the influence of constant and time variable BHF on drawing force (DF) and thickness distribution in the deep drawing process of cylindrical and square cups. A finite element model was developed in the AutoForm software and validated with experiments. The developed model has been used for the simulation of deep drawing process of AA6016-T4 aluminum alloy sheet. The experimental and numerical results show that, using a variable instead of a constant BHF, the DF can be decreased in the expense of wall thickening.

Devendar.G, A. Chennakesava Reddy[5] Study on Deep Drawing Process Parameters - A Review (2016). Deep drawing is one of the most important processes for forming sheet metal parts. It is widely used for mass production of cup shapes in automobile, aerospace and packaging industries. The quality of the product is influenced by the many of the process parameters like blank holder force, co efficient of friction, strain rate, thickness, temperature, punch force and punch speed etc. So a good knowledge is required to produce good quality of deep drawing products by minimizing the defects. In this review paper importance is given to gather the recent research work and developments in the area of deep drawing.

III. SIMULATION

In this project, the Solid Edge V19 is used to create the CAD models in .STL format and AFDEX_V16 is used to simulate the deep drawing process. Metal forming software (AFDEX-2016) will be used in this project to design and simulate the metal forging process. AFDEX is a general purpose metal forming simulator, which can be applied not only to conventional bulk metal forming processes including forging, rolling, extrusion, and drawing, but also to new creative bulk metal forming processes. AFDEX is theoretically based on the rigid-thermoviscoplastic finite element method. AFDEX can solve the metal flow and heat transfer problems present in metal forming and die structural analysis.

IV. METHODOLOGY

The steps involved in the simulation of deep drawing process are shown in fig. 2. It starts with the CAD modeling of dies and workpieces. SolidEdge v19 is used to design the CAD models. These are converted to .STL formats since AFDEX only accepts .STL files. Cold forming method is selected for the deep drawing process where the temperature is maintained at 25ºC.Different combination of design and process parameters are considered. AFDEX simulation software is used to simulate the deep drawing process and results are analyzed for any defects or imperfections. In this project the parameters considered for optimization are binder holding force, die corner radius and punch velocity. Whereas ce-efficient of friction and initial temperature are kept constant. Binder holding force is varied in the range of 1265±250N. Die corner radius are 3,4,5,6,7mm respectively. Punch velocity is varied in the range 230±25 mm^{-s}. Meshing are kept in auto configuration and a total of 15 simulations are performed in AFDEX. Results are tabulated and analyzed.

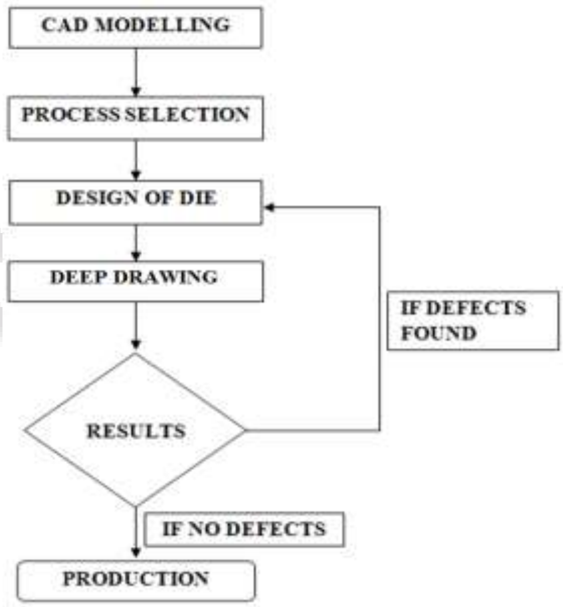

Fig. 2: Steps involved in simulation

The design assembly of cup and dies is shown in fig.3.

Component	Cup
Material Used	AISI 304
Forming Type	Cold
Number of draws	1
Initial Billet Temperature	25^{0}C

Table 1: Details of the Component

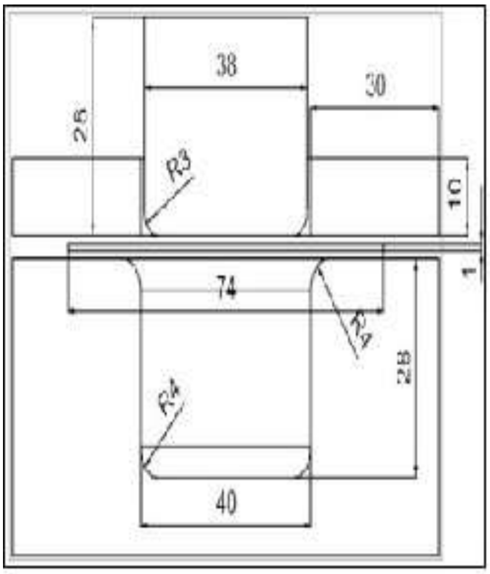

Fig. 3: Design assembly of cup

V. RESULTS

Three different parameters have been considered in this project and their effect on damage value and thickness distribution on the deep drawn cup is analyzed. The following are the respective cases:

A. *Case 1: Variable Binder Holding Force*

Sl. No.	BHF (N)	Effective Strain	Effective Stress (MPa)	Damage Value
01	765	8.64391E-001	3.58503E+002	2.73298E-001
02	1015	8.37769E-001	3.51744E+002	3.01434E-001
03	1265	8.63879E-001	3.58666E+002	2.81372E-001
04	1515	8.78315E-001	3.60999E+002	2.75144E-001
05	1765	8.39249E-001	3.49524E+002	3.02892E-001

B. *Case 2: Variable Die Corner Radius*

Sl. No.	Die Corner Radius (mm)	Effective Strain	Effective Stress (MPa)	Damage Value
01	3	9.05079E-001	3.63729E+002	3.74573E-001
02	4	8.92826E-001	3.63480E+002	3.15733E-001
03	5	8.63879E-001	3.58666E+002	2.81372E-001
04	6	8.59467E-001	3.57558E+002	2.63095E-001
05	7	8.00977E-001	3.45670E+002	2.52708E-001

C. *Case 3: Variable Punch Velocity*

Sl. No	Punch Velocity (mm/s)	Effective Strain	Effective Stress (MPa)	Damage Value
01	180	8.78490E-001	3.61280E+002	2.82633E-001
02	205	8.76389E-001	3.60604E+002	2.90277E-001
03	230	8.63879E-001	3.58666E+002	2.81372E-001
04	255	8.89518E-001	3.62637E+002	2.90257E-001
05	280	8.65246E-001	3.58902E+002	2.80786E-001

Total 15 iterations were performed and the damage values were tabulated.. Following figures represents the damage value and load value of three iterations with minimum values.

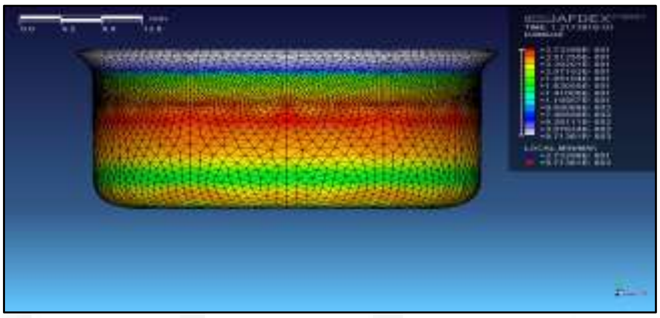

Fig. 4: Damage value of cup drawn with BHF 765N.

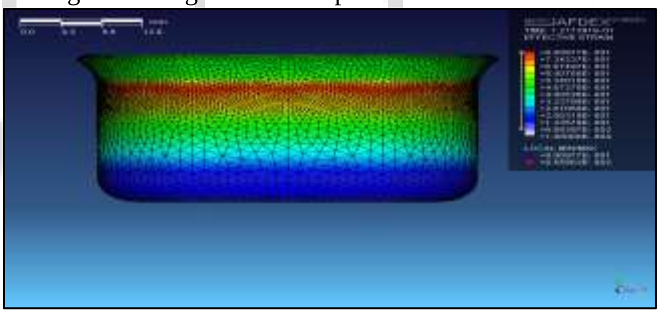

Fig. 5: Damage value of cup drawn with die corner radius 7mm.

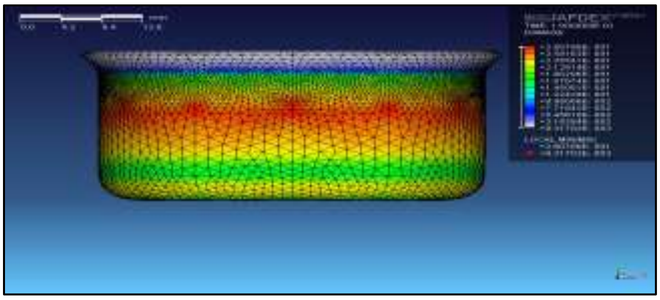

Fig. 6: Damage value of cup drawn with punch velocity 280mm-s

VI. THICKNESS DISTRIBUTION

The thickness of the drawn cup is not constant. It keeps on changing from the center of the cup to the exterior edge. Let 1, 2, 3, and 4 be the points on the cup from the centre of the cup towards its upper corner as shown in below figure. In our study the initial thickness of the blank in 1mm. After deep drawing the thickness at all the four points is not same.

Thickness is minimum at point 2 and maximum at point 4. The various design and process parameters play a crucial role in thickness distribution throughout the component. The following tables and graphs show the effect of BHF, die corner radius and punch velocity on thickness distribution.

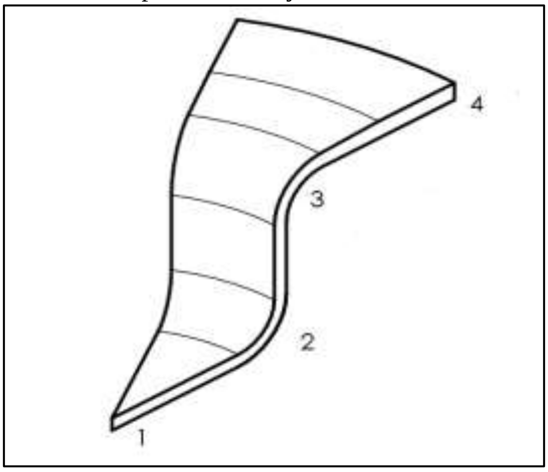

Fig. 7: Points 1, 2, 3, and 4

Following are the graphical representation of the thickness distribution at points 1, 2, 3, and 4.

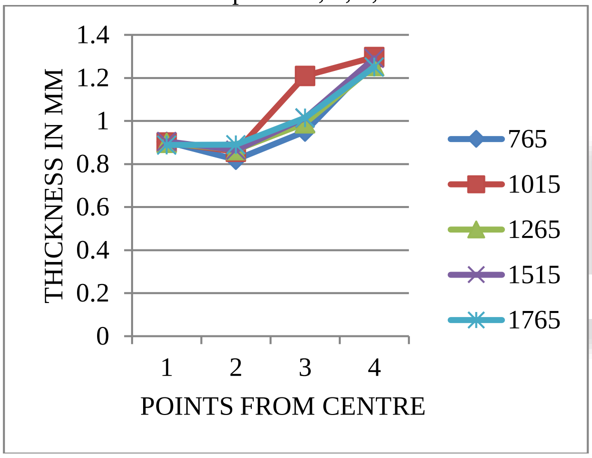

Fig. 8: Thickness Distribution for Case 1

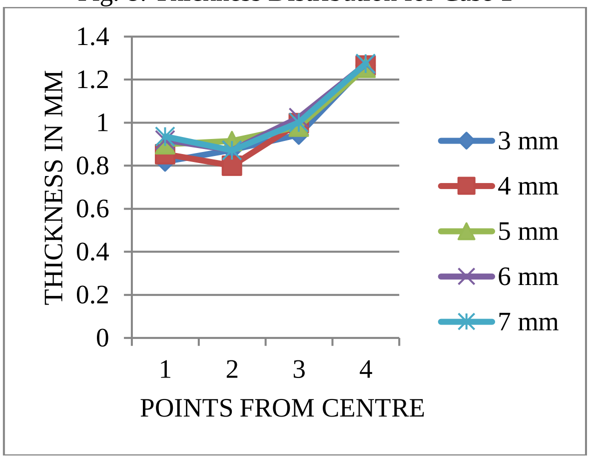

Fig. 9: Thickness Distribution for Case 2

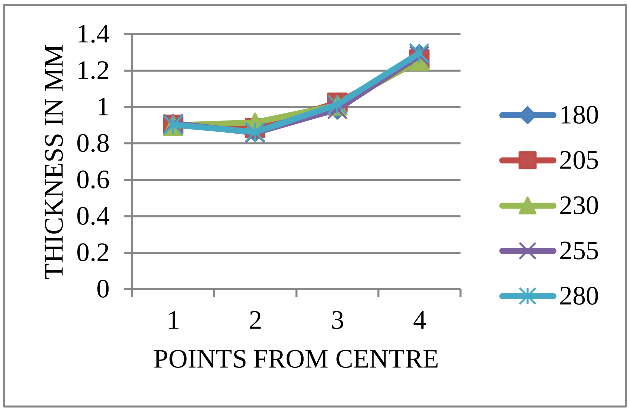

Fig. 10: Thickness Distribution for Case 3

VII. CONCLUSIONS

Deep drawing is one of the most important sheet metal forming process. In this project 15 iterations were performed in AFDEX simulation software. Three cases were studied and in each case five simulations were performed. Binder holding force, die corner radius and punch velocity were changed and other parameters were kept constant. Results were tabulated and from the results we can see that these parameters are very important in deep drawing of sheet metal and should be kept in optimum range. It can also be seen when these parameters were changed, thickness distribution in the final drawn component also gets changed. From results we get optimized parameters in each case and are as follows,

A. *CASE 1: Variable Binder holding Force*

Damage value was found to be minimum when the BHF was 765N with a value of 2.73298E-001. Other parameters were,

- Punch Velocity = 230mm^{-s}
- Die corner radius = 5mm
- Friction Co-efficient (μ) = 0.05

B. *CASE 2: Variable Die Corner Radius*

Damage value was found to be minimum when the die corner radius was 7mm with a value of 2.52708E-001. Other parameters were,

- Punch Velocity = 230mm^{-s}
- Friction Co-efficient (μ) = 0.05
- Binder Holding Force = 1265N

C. *CASE 2: Variable Die Corner Radius*

Damage value was found to be minimum when the punch velocity was 280mm^{-s} with a value of 2.80786E-001. Other parameters were,

- Die corner radius = 5mm
- Friction Co-efficient (μ) = 0.05
- Binder Holding Force = 1265N

It is clearly evident that damage value obtained for the above said parameters is least as compared to other iterations.

The following conclusions can be drawn from the results,

Binder holding force, die corner radius and punch velocity are very important parameters that need to be considered for deep drawing process. The values of these parameters should be optimized because they have great impact on deep drawing process.

Thickness distribution in the drawn cup is not same throughout is body. It changes form point to point. Change in the thickness distribution was also studied and we can conclude that a change in the values of BHF, die corner radius and punch velocity will lead to change in the thickness distribution in the overall cup.

Final deep drawn cup will be free of all surface defects since there is no folding on the surface and within the component. Hence a defect free component can be drawn using the above combination of parameters.

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