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DEPARTMENT OF MECHANICAL ENGINEERING

SEMINAR ON

FINITE ELEMENT ANALYSIS OF COLD DEEP DRAWING PROCESS FOR CYLINDRICAL CUPS OF AA- 1100

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INTRODUCTION

- Deep drawing process is an essential process used for producing cups from sheet metal in large quantities. It is a tensile compression forming process in which usually an open-top metallic hollow body is created.This process is widely used in automobile, aerospace, electronics and allied industries to produce hollow parts. This is a sheet metal forming process in which a sheet metal blank is radially drawn into a forming die by the mechanical action of a punch.

- The process is considered "deep" drawing when the depth of the drawn part exceeds its diameter..

BENEFITS:

1. High productivity
2. Eliminates assembly steps
3. Seamless.
4. High accuracy.
5. Produces complex geometries.
6. Produces very strong parts
7. Cost

PROCESS:

- Starting with a metal blank, the disc of metal cut from a larger sheet is pushed into a cavity around a die, which begins the deep drawn process of drawing the blank into the desired shape. This is completed in gradual steps to ensure an even distribution of the metal across the final shape, which is important for preserving the integrity and strength of the finalised deep-drawn component.

- The rigid tools consist of a punch, die and binder.The sheet is clamped between the die and the binder. This process slows down the flow of the sheet while it is being drawn and thereby prevents wrinkles from forming under the binder. The punch stretches the sheet over the die radius and forms it in the die. The amount of punch force necessary for forming is thereby continuously increased up to the lower deadcenter of the punch.

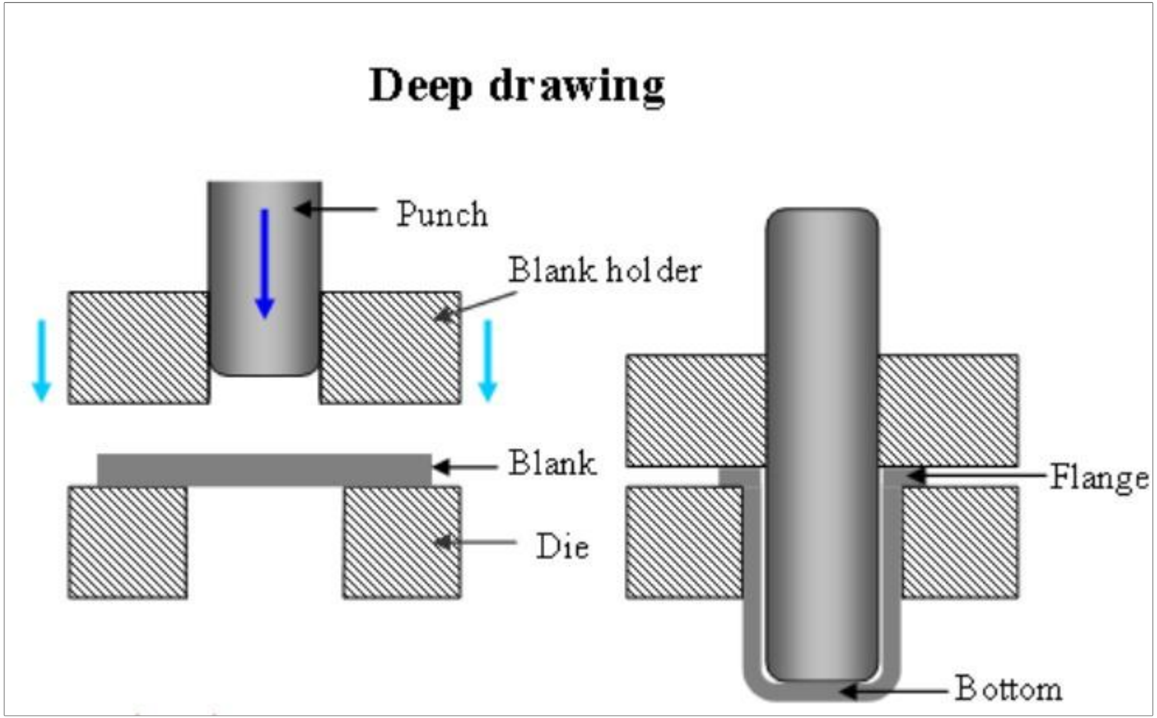


Fig: Deep drawing process

Image source: http://www.substech.com/dokuwiki/doku.php?id=deep_drawing

LITERATURE REVIEW

- D.Swapna et al “A Review On Deep Drawing Process”

Deep Drawing process is the one in which a punch forces a flat sheet metal blank into a die cavity. Deep Drawing can also be described as the process which involves conversion of flat thin sheet metal blanks into parts of desired shape. Little work is available in the applications of Deep drawing processes at elevated temperatures which is going to be a very important manufacturing application in the coming decades. Deep Drawing is one of the sheet metal forming processes widely used in automobile, aerospace, electronics and allied industries to produce the hollow parts. The improvement in the deep drawing manufacturing process with latest methodologies leads to developments in the automobile and other sheet metal industries. Still today, this process of analysis and design is an art than science. Presently, the conventional deep drawing (CDD) operation is carried out at room temperature in industries. Although the deep drawing process of high strength / low formability metals has an extensive industrial application area, deep drawing at room temperature has serious difficulties because of the large amount of deformations revealed and high flow stresses of the materials. This paper gives an overview of deep drawing process, its classification along with advantages, limitations and applications.

- Blaza Stojanovic et al "Application Of Aluminum And Aluminum Alloys In Engineering"

  The paper deals with the considerations related to the basic properties and application of aluminum alloys and composite materials for different purposes which focus on the automotive industry. Through the description of the basic characteristics of aluminum alloys, the starting points for their application in different technical systems are given. On the other hand, the advantages and disadvantages of the use of certain aluminum alloys, along with the guidance and compounds and elements whose use is further enhanced and enriched by aluminum alloys, are predominantly presented. The application of aluminum alloys in the automotive industry, as well as the particular types of aluminum based materials used for individual aggregates and circuits of motor vehicles, as well as their behaviour in different operating modes are described. Ultimately, the advantages that are primarily achieved with the vehicle are obtained by the use of aluminum alloys and composites. The conclusion that there is still space in the field, further improvement of the characteristics of aluminum alloys.

- A.R.Joshi et al”Effects Of Different Parameters On Deep Drawing Process”

  The formability of sheet metals is affected by many parameters, like material parameters, process parameters, etc. For determination of the optimum values of the process parameters, it is essential to find their influence on the deformation behavior of the sheet metal. The significance of three important process parameters namely, punch radius, blank holder force and friction coefficient on the deep drawing characteristics of a mild steel cup were determined. By analyzing these parameters, the defects like wrinkling, tearing, earing is reduced and also we can get the good quality product. There are many processing and material parameters which are affecting deep drawing process. Some of the functions are there which cover most of the material and processing parameters affecting the thickness distribution and also the quality of the product.

- G.Devendar et al”Formability Limit Diagrams Of Cold Deep Drawing Process For Nickel 201 Cylindrical Cup”

  The process parameters were punch velocity, coefficient of friction, strain rate and displacement per step. The formability of deep drawn cylindrical cups were also constructed. The results obtained from the finite element software namely D-FORM were validated experimentally. The strain rate by itself has a substantial effect on the effective stress, surface expansion ratio, damage and height of the cylindrical cups drawn. The extending deformation of grain boundary micro-voids towards the tensile direction would contribute more to the total elongation, as the strain rate increases; this should be the most possible reason for the increase of surface expansion ratio with an increase in the strain-rate. The plastic deformation increases with the extended yield strength, consequently the damage decreases

OBJECTIVE

- Deep drawing is a sheet metal forming process in which a sheet metal blank is radially drawn into a forming die by the mechanical action of a punch.

- It is thus a shape transformation process with material retention. The process is considered "deep" drawing when the depth of the drawn part exceeds its diameter. As the blank is drawn radially inwards the flange undergoes radial tension, circumferential compression.

- Wrinkling in the flange occurs due to compressive buckling in the circumferential direction. Tearing occurs because of high tensile stresses that cause thinning and failure of the metal in the cup wall.

- Our objective is to find the optimal procedure for deep drawing cups with least effects and high limiting drawing ratio.

GOAL

- The variables that affect the metal during deep drawing are Radius of punch ,Draw radius of the die ,speed, load ,Die Clearance, Friction. The important factor for a deep drawing process is the ductility of material. Another factor that increases load on forming equipment is the rate at which the forming process is carried out.

- At higher rates of strain the flow stress of material increases leading to higher loads on the equipment. When a forming process is carried out the recrystallization is also present along with strain hardening and strain rate effect. Friction is an important parameter that influences the deep drawing process. In metal forming processes, friction influences the strain distribution at tool blank interface and drawability of metal.

- A finite element method is developed to study the elastic-plastic deformation of sheet materials in the presence of large strains and large displacements.

- The sheet is assumed to be isotropic ,The method is used for modelling deep-drawing with the appropriate boundary conditions, Numerical solutions are compared with the experimental results.In the present work, the formability of cold deep drawing process was assessed during the fabrication of aluminium 1100 cylindrical cups. We focussed on the parameters such as Punch velocity, mm/s,Coefficient of friction ,Strain rate and Displacement per step . The cold deep drawing process was executed using the finite element analysis software DEFORM - 3D.

MATERIALS AND USES :

ALUMINIUM ALLOY 1100:

Aluminum 1100 is among the softest aluminum alloys and therefore is not used for high-strength or high-pressure applications. Cold-working is the most common way to form **Aluminum 1100.** It is just one of several common aluminum alloys and is soft, low strength and, has 99% min aluminum, is the commercially pure aluminum. Copper, iron, magnesium, manganese, silicon, titanium, vanadium and zinc comprise the remaining elements. It cannot be hardened by heat treatment and is very formable.

Alloy composition of 1100 aluminium ,%,of ALUMINIUM ALLOY 1100

Aluminium……………………………………………………..99.0–99.95%

Copper………………………………………………………...0.05–0.20%

Iron……………………………………………………………..0.95% max

Manganese…………………….……………………………...0.05% max

Silicon…………………….…………………………….....:0.95% max

Zinc……………………………………………….…………0.1% max

Residuals…………………….…………………………………..0.15% max

Features:

1. Corrosion resistant
2. Durable functioning
3. Malleable
4. Heat resistant
5. High strength
6. Excellent conductivity
7. Impeccable finish
8. Enhanced service life
9. Precisely designed

USES:

Aluminum 1100 can be shaped into many different products, including chemical equipment, railroad tank cars, fin stock, dials, name plates, cooking utensils, rivets, reflectors and sheet metal. The plumbing and lighting industries also use aluminum 1100, as do a wide variety of other industries.

SOFTWARE AND DESIGN PARAMETERS:

- **DEFORM** is tailored for deformation modelling . A user friendly graphical user interface provides easy data preparation and analysis so engineers can focus on forming.
- **DEFORM-3D** is a powerful process simulation system designed to analyze the three-dimensional (3D) flow of complex metal forming processes.
- **DEFORM** is the most widely used simulation program in the world by leading research institutes and manufacturers.
- An advanced mesh generator automatically applies an adaptive, optimized mesh to parts and tooling. This captures important model detail while minimizing the simulation time.

Typical applications include:

- Closed die forging
- Open die forging
- Machining
- Rolling
- Extrusion
- Heading
- Drawing

CONTROL PARAMETERS :

- ALUMINIUM 1100 was used to fabricate cylindrical cups. For the finite element analysis, the chosen control parameters are summarized below. In the present work, the formability of cold deep drawing process was evaluated during the fabrication of aluminium alloy 1100 cylindrical cups. The investigation was focused on the process parameters such as punch velocity, coefficient of friction, displacement per step and strain rate.

Factor	Symbol	Level
Punch velocity, mm/s	A	5
Coefficient of friction	B	0.1
Strain rate, 1/s	C	100
Displacement per step, mm	D	0.75

DESIGN OF DEEP DRAWN CUPS:

➢ The blank size was calculated by equating the surface area of the finished drawn cup with the area of the blank. The diameter of the blank is given by:

- D = $\sqrt{d^2 + 4dh}$ for (d/r < 20).................................... (1)
- D = $\sqrt{d^2 + 4dh}$ - 0.5r for (20<d/r < 20) ....(2)
- D = $\sqrt{d^2 + 4dh}$ - r for (10< d/r < 15)............................ (3)
- D = $\sqrt{(d-2r)^2 + 4d(h-r) + 2\pi r(d-0.7r)}$ for (2d/r < 10).....(4)

Where d is the mean diameter of the cup (mm), h is the cup height (mm) and r is the corner radius of the die(mm). Where D is the diameter of the blank before operation (mm). t is the thickness of the cup (mm) and σ is the yield strength of the cup material (N/mm^2)

➢ The drawing ratio (**DR**) is roughly calculated as, **DR** = D/d.

➢ The force required for drawing depends upon the yield strength of the material σ_y, diameter and thickness of the cup.

- Drawing force, $F_d = \pi dt\left[\frac{D}{d} - 0.6\right]\sigma_y$

The drawing punches must have corner radius exceeding three times the blank thickness (t). However, the punch radius should not exceed one-fourth the cup diameter (d).

$3t < \text{Punch radius} < d/4$

- The corner radius of the die can be calculated from the below equation.

  - $r = 0.8\sqrt{(D-d)t}$

For smooth material flow, the die edge should have generous radius preferably four to six times the blank thickness but never less than three times the sheet thickness because lesser radius would hinder material flow while excess radius the pressure area between the blank and the blank holder, and would cease to be under blank pressure.

The material flow in drawing may render some flange thickening and thinning of walls of the cup inevitable. The space for drawing is kept bigger than the sheet thickness. This space is called die clearance, which is given by

- $c = t + \mu\sqrt{10t}$

This clearance is added on the either sides of the punch die while designing the dies for the drawing operation.

FINITE ELEMENT MODELING ANALYSIS:

- Using D-FORM 3D software finite element modeling and analysis is done. First cylindrical blank sheet is created with desired diameter and thickness with calculated parameters using cad tools.Then material properties are assigned using predefined materials in the material library. For this experiment ,Aluminum 1100 is selected.

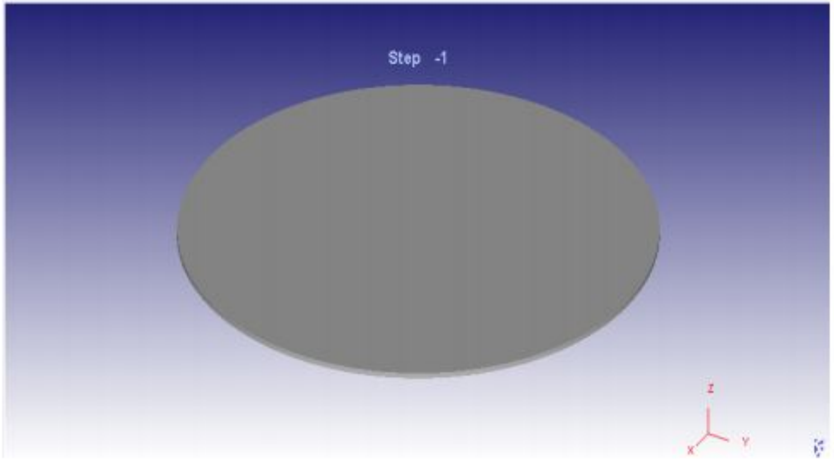


Fig : Cylindrical blank sheet

After adding material ,meshing is done. Discretisation is done with tetrahedron elements with minimum size of 1 mm and size ratio of 2.5. The number of elements were observed to be 20,000 .

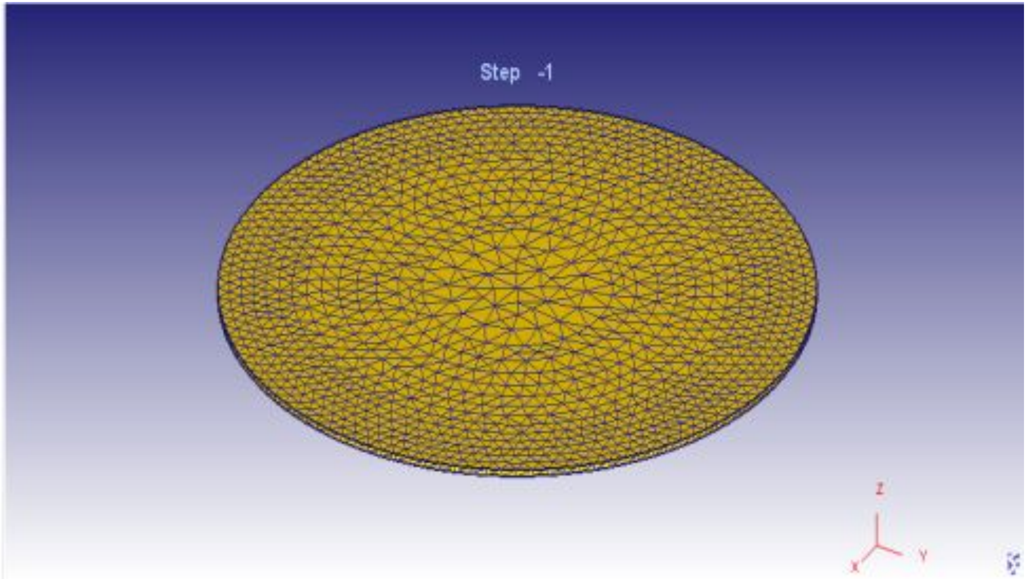


Fig : Mesh generation of cylindrical blank sheet

In the next operation top die modeling is done. The top die is designed using the CAD tools as per dimensions obtained from the design equations.

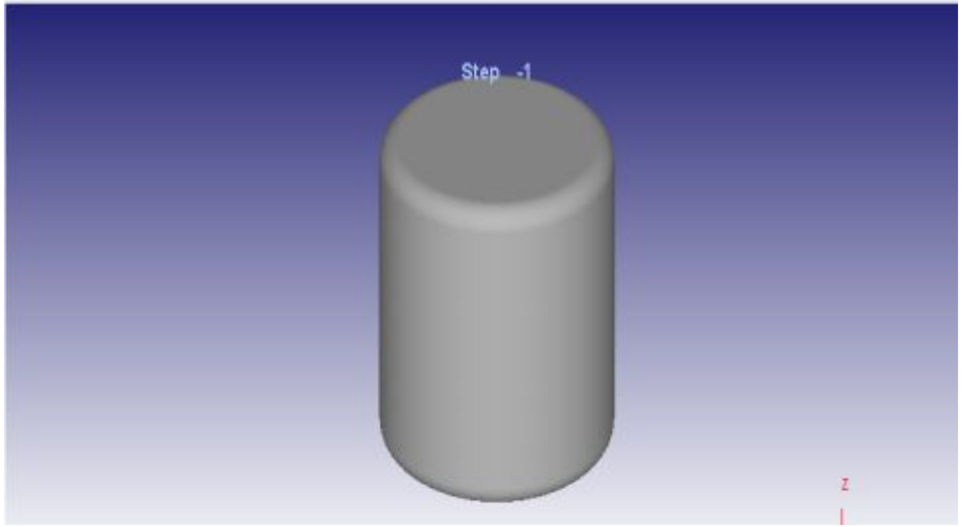


Fig 6 : Top die

Then bottom die also designed using the dimensions from design equations

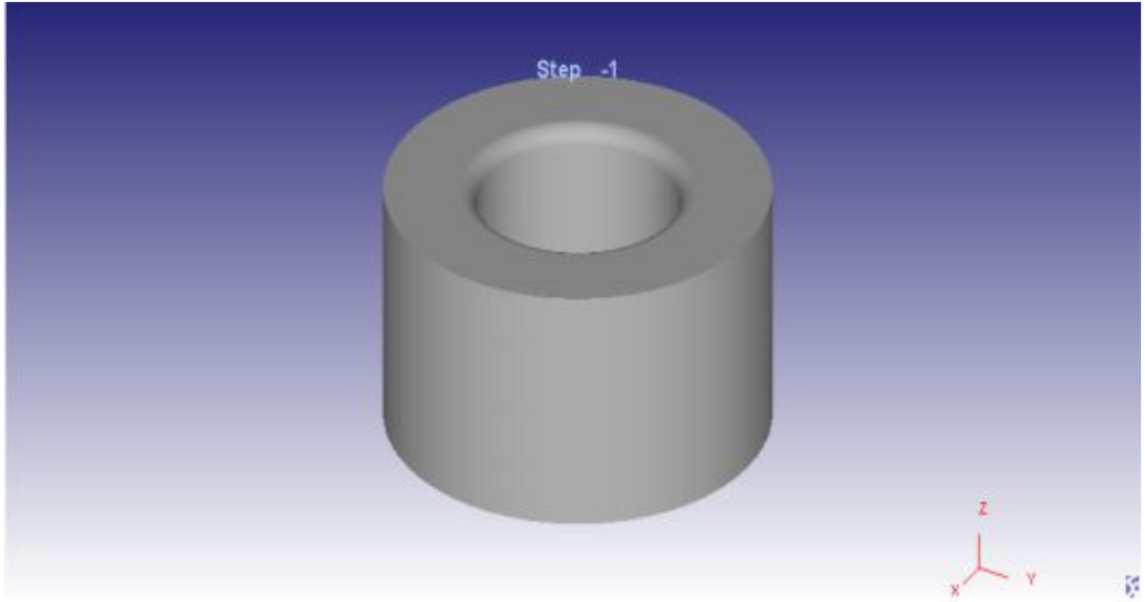


Fig : Bottom die.

Then the dies should be assembled before simulation.Initially dies and blank will be at the same point by default, so select automatic position .So, the automatic positioning is similar as the figure given below.

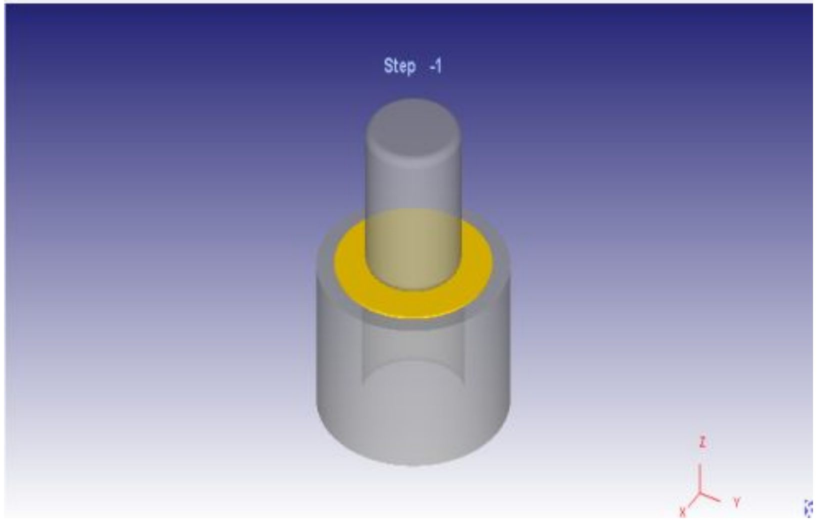


Fig : Assembly of blank and dies

The control parameters are assigned according to the values given in the control parameters table shown, and simulations are carried out in the “Simulation operation” of the software. After simulation, the cup will be formed.

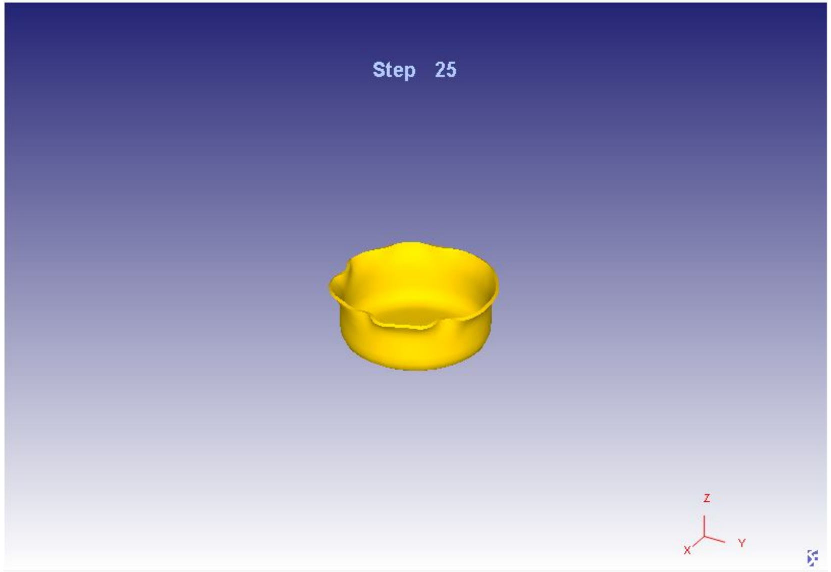
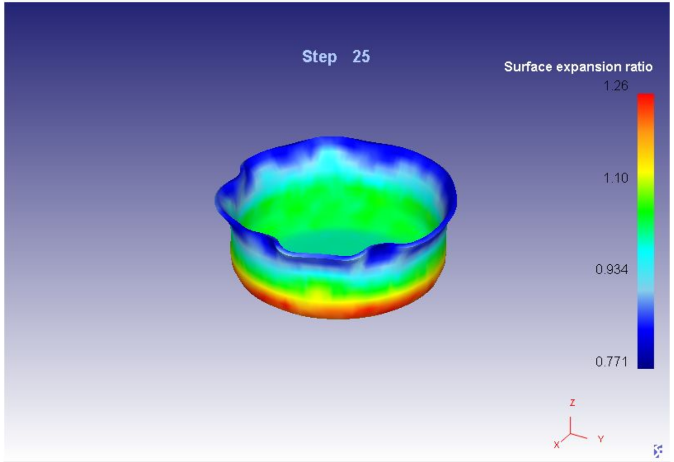


Fig : Final Deep drawn cup

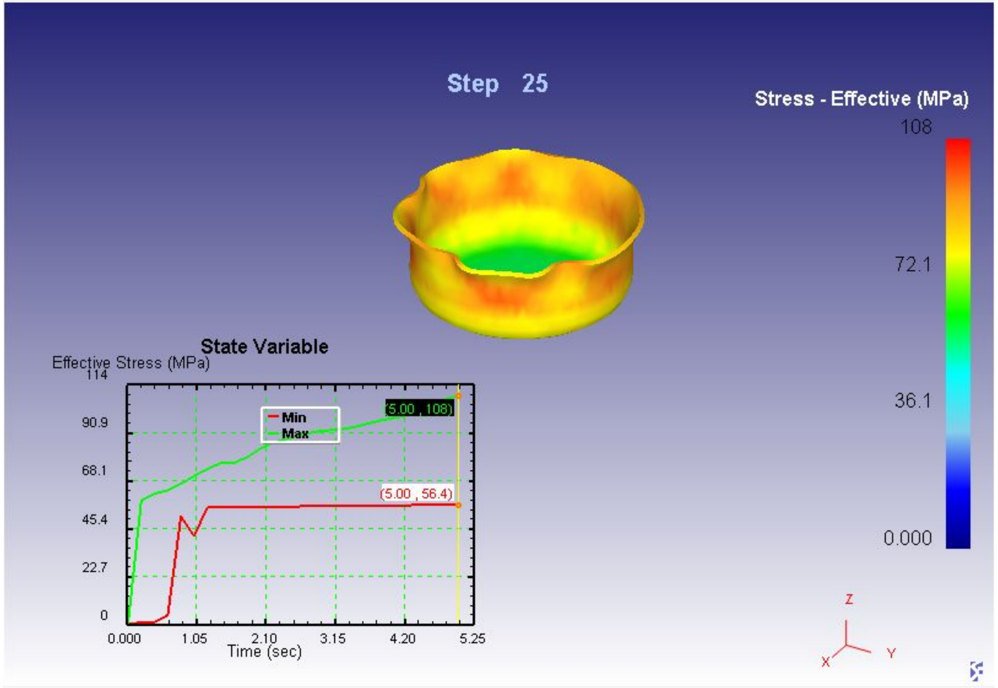
RESULTS :

After completing the simulation we can see the variation of values and corresponding graph of formed cup in various stages of forming. The observed values include surface expansion ratio, effective stress, damage and total displacement.

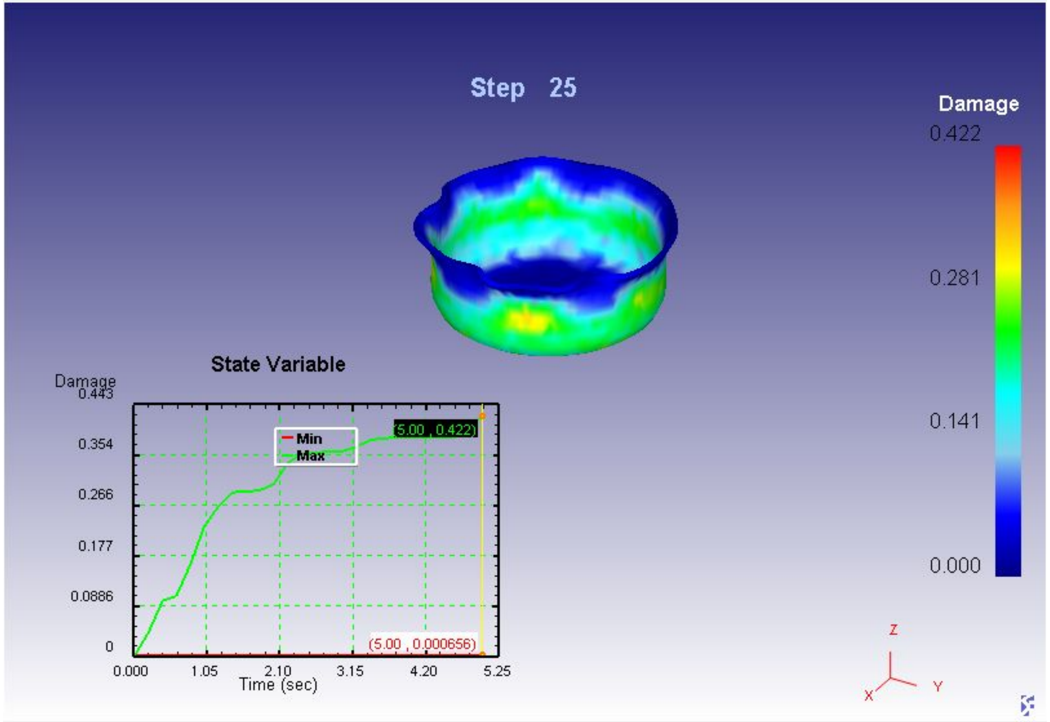
● The final cup image showing the surface expansion ratio . The maximum surface expansion ratio obtained from this trial is 1.26 .



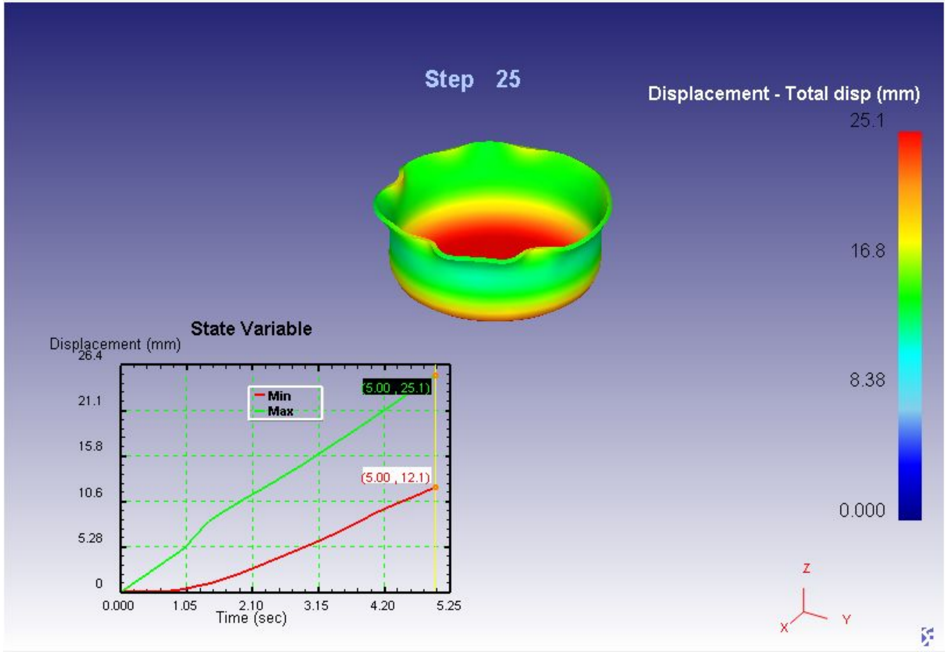
● The final cup image showing the effective stress and corresponding graph. The maximum effective stress obtained from this trial is 108Mpa.



- The final cup image showing the damage values and corresponding graph. The maximum damage value obtained from this trial is 0.422



● The final cup image showing the total displacement (mm) and corresponding graph. The maximum total displacement obtained from this trial is 25.1 mm.



CONCLUSION :

In the present work, AA 1100 was used to fabricate cylindrical cups. The investigation was focused on the process parameters such as punch velocity, coefficient of friction, displacement per step and strain rate. The major process parameter which could influence the quality of the cup was the strain rate and displacement per step. The observed values are surface expansion ratio is 1.26, stress effective value is 108 Mpa , damage value is 0.422, total displacement is 25.1mm .

REFERENCES

1. A.R.Joshi, K.D.Kothari,Dr.R.LJhala, Paper titled Effects Of Different Parameters On Deep Drawing Process,IJERT,2013
2. G.Devendar, A.Chennakesava Reddy, Research Paper titled Formability Limit Diagrams Of Cold Deep Drawing Process For Nickel 201 Cylindrical Cup,at IJSR, 2016
3. Blaza Stojanovic , Milan Bukvic , Igor Epler, paper titled Application Of Aluminum And Aluminum Alloys In Engineering,2018
4. D.Swapna ,Ch.Srinivasa Rao,S.Radhika, research article named A Review On Deep Drawing Process,IJERT,2017
5. http://www.substech.com/dokuwiki/doku.php?id=deep_drawing
6. https://www.deform.com/wp-content/uploads/2015/06/DEFORM-3D-Machining.pdf

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