THEORETICAL AND EXPERIMENTAL ANALYSIS OF CUP DRAWING ON 40T MECHANICAL PRESS

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Abstract - *Metal forming is a major practice in industries for various components like Bending, Wire Drawing, Cup Drawing, Deep Drawing etc. For drawing the force parameter is an important one and also stresses and strains. Plate thickness is reduced during Deep Drawing process called as Ironing.An attempt is made to study the Drawing force, experimentally and by simulation. Drawing forces are calculated based on the plastic deformation during Cup Drawing An DEFORM package is used. Using DEFORM package the stresses and strains within the plate are estimated. Experiments were conducted on three different materials of different thickness viz... Mild Steel, Copper, Aluminium. Practically measured forces are obtained using piezo electric load cell. Practically obtained forces and theoretically calculated forces are compared and the maximum deviation is 41 % in case of Copper and in the same way the forces obtained using DEFORM package and Theoretical manner are also compared the maximum deviation is 4.98 %for Aluminium. The stress values are Maximum just above the bottom portion of the Cup strains are also following the same trend as stresses. Least stress and strains are observed at the bottom of the Cup .The maximum stress is observed where the maximum strain occurs.*

Key Words: Deform,**catiya, FEM (Finet Element Method),** Mild Steel, Copper, Aluminium

1 INTRODUCTION

Drawing is a process of cold forming a flat, precut metal blank into a hollow vessel without excessive wrinkling, thinning, or fracturing. The various forms produced may be cylindrical or box shaped, with straight or tapered, and curved sides. The parts may vary from 6.35mm diameter or smaller to air craft or automotive parts large enough to require using of mechanical handling equipment.

1.1 Deep Drawing Of Cylindrical Cup 1

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

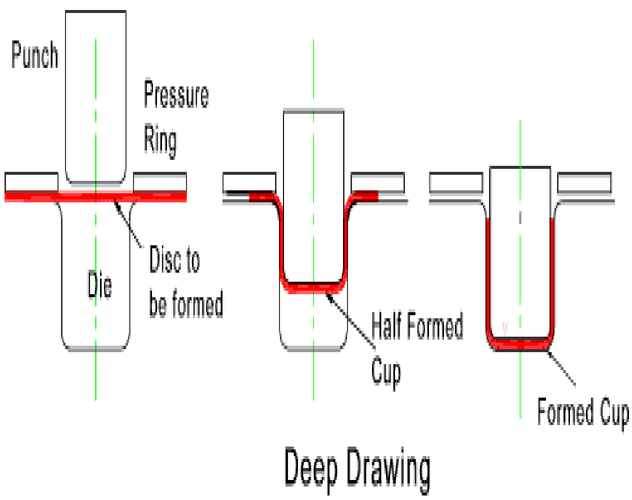


Fig1 - The process of Deep Drawing.

When a punch of a drawing press forces of a metal blank through the bore of the drawing, different forces come into action fig[1.2] causing a complicated plastic flow of the material. The volume and thickness of metal remain constant, and the final shape of the cup will be similar to the contour of the punch. The progressive stages of cupping are schematically shown in the following fig [1.3] after a small stroke of a punch; cupping stage A, the metal volume element 2 of the blank is bent and wrapped around the punch nose. Simultaneously, the outer portions of the blank, showed by sections 3, 4 and 5 move radically towards the centre of the blank, as shown in cupping stages B and C. The various volume elements decrease in circumferential length and correspondingly increase in radial length and in that direction as long as it reaches the bore of the drawing. After bend over, conforming to the edge of the die the shell elements are straight. During Drawing, area 1, for the specific example illustrated, is unchanged in the bottom of the cup. The areas which become the sidewalls of the shell (2, 3 and 4) change from the shape of angular segments to longer parallel sided shapes as they are drawn over the inner edges of the drawing, from this point no further metal flow takes place.

1.2 In general the metal flow by cupping may be summarizing as follows 2

Little or no metal deformation takes place in the blank area, which forms the bottom of the cup. This is indicated by the unchanged distances between the marking lies and the radial in the base of the shell.

The metal flow taking place during the forming of the cup wall uniformly increases cup height. This is indicated by the marking lines, which remain concentric but also become parallel when they assume their final dimensions in the cup wall.

The metal flow of the volume thickness is caused by severe circumferential compression. The increase is usually slight because it is by the clearance of the punch and the bore wall of ring. Shows the deformation during drawing.

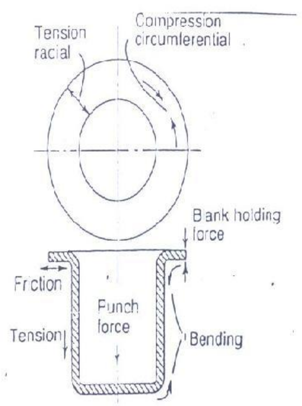


Fig2: - Forces involved in metal flow during cupping.

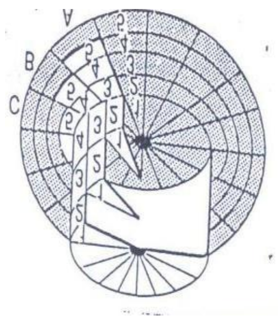


Fig3:-step-by- step flow of metal

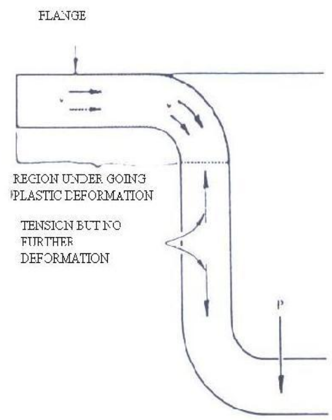


Fig4:- the pattern of Deformation

1.3 wrinkling and puckering 3

The shaping of a shell necessitates severe cold working and involves plastic flow of metal. The formation of wrinkles in the flange area is to be expected since the direction of the stresses is circumferential. When the diameter- thickness ratio is high blank holding pressure is required; when this ratio is high, high blank holding pressure is required; when this ratio is low, little or no blank holder pressure is required. SHEET METAL DRAWING OPERATIONS: The shape of the part drawn is the characteristic used to classify the operation. Drawn part fall into the following categories:**Cupping, DrawingBox,Drawing Deep**

1.4 Cupping 4

Cupping is the drawing of parts having circular or cylindrical shapes.

1.5 DRAWINGBOX 5

The Drawing of square or rectangular shape is called the box drawing.

1.6 Deep Drawing 6

The metal in this region is subjected to biaxial tensile stress due to the action of the punch. Metal in the outer portion of the blank is drawn radially inward toward the throat of the die.

1.7 Literature Survey 7

Deep drawing process varied includes the punch and die radii, the punch velocity, clamping force, and friction and draw depth. A deep drawing rig was designed and built for this purpose. Punches and dies of various geometries were manufactured. From previous FEA work and the experimental work performed to date, 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.

1.8 DEFORM 8

DEFORM is a Finite Element Method (FEM) based process simulation system designed to analyze various forming and heat treatment processes used by metal forming and related industries. Reduce the need for redesign of tooling and processes, Improve tool and die design to reduce production and material costs,Shorten lead time in bringing a new product to market.

1.9 Capabilities 9

Coupled modeling of deformation and heat transfer for simulation of cold, warm, or hot forging processes. Extensive material database for many common alloys including steels, aluminums, titanium's, and super-alloys. Contour plots of temperature, strain, stress, damage, and other key variables simplify post processing, Fractureinitiation and crack propagation models based on damage factors allow modeling of shearing, blanking, piercing, machining. ANALYZING **MANUFACTURING PROCESSES WITH DEFORM: Define your** proposed process Final forged part geometry, Material, Tool progressions, Startingwork piece/billet geometry, Processing temperatures, reheats, etc. Using DEFORM pre-processor, input the problem definition, Submit the data for simulation, Using the DEFORM post-processor, review the results, Repeat the preprocess-simulate-review sequence for each operation in the process

2. THE DEFORM SYSTEM 2

A pre-processor for creating, assembling, or modifying the data required to analyze the simulation, and for generating the required database file. A simulation engine for performing the numerical calculations required to analyze the process, and writing the results to the database file. The simulation engine reads the database file, performs the actual solution calculation, and appends the appropriate solution data to the database file. The simulation engine also works seamlessly with the Automatic Mesh Generation (AMG) system to generate a new FEM mesh on the work piece whenever necessary. While the simulation engine is running, it writes status information, including any error messages, to the message (.MSG) and log (.LOG) files.A post-processor for reading the database file from the simulation engine and displaying the results graphically and for extracting numerical data.

2.1 Aluminum-Magnesium-Silicon Alloy 6061 1

This group includes magnesium (Mg) and silicon (Si) as the major alloying elements. Copper, manganese, chromium, zinc, boron, lead and bismuth may be added to the alloys of 6xxx series as minor alloying elements. Alloys of this series possess high mechanical strength combined with good formability and corrosion resistance.

2.2 Typical Properties Of Aluminium Alloy 6061 Include 2

Medium to high strength Good toughness and surface finish, excellent corrosion resistance to atmospheric conditions, High Ductile in nature.

Table -1: Alloying element composition of 6061 Aluminium alloy.

ALLOYING ELEMENT COMPOSITOIN											
Weight (%)	Al	Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	Others each	Others total
6061	Bal	0.40-0.80	0.70 max	0.15-0.40	0.15	0.80-1.20	0.04-0.35	0.25 max	0.15 max	0.05	0.15 max

2.2 Work Bench 2

Work bench is defined as a specified environment consisting of a set of tools, which allow the user to perform the specific design tasks in a particular area. The basic work benches available in CATIA V5 are: Part Design Workbench, Assembly design work bench, Drafting Work bench, Wire frame and Surface Design Work bench.

2.3 Dimensions Of The Parts 3

punch height45 mm, punch diameter20 mm, bottom die height-55mm, bottom die inner diameter 22 mm , punch speed 0.5 mm/sec, Blank diameter50 mm.

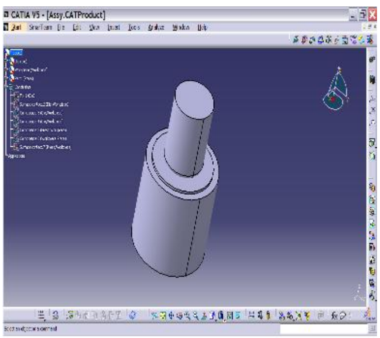


Fig 5 - A picture of cup drawing

3. PROCEDURES FOR SIMULATION IN DEFORM 3

Open DEFORM-3D, go for a new file, and choose problem type as deform-3D Pre-processor, set the file location where it has to be stored, set the problem name. Deform-3D pre-processor opens up in a new window. Open up simulation control and change the units to S.I Select the mode as Deformation.Set the current object to work piece and set the object type to be plastic. Now import the geometry from CATIA in .IGES format. The important step after importing the object is checking for its geometry and it is done by clicking on the "check & correct geometry "button.It is the most important step, Click on the "BCC" button, select contact and then the blank should have a contact point at the top side. Now add a new object and change the object name to die no., followed by object to be rigid. Choose it as primary die. Go for geometry, import appropriate die from CATIA drawings. Repeat the same procedure for bottom die.Now, database is checked and generated by clicking on the "Data Base generated "button. After data base is generated, it is saved and window is exited. A post-processor is used for reading the data base file from the simulation engine and displaying the results graphically and for extracting numerical data.

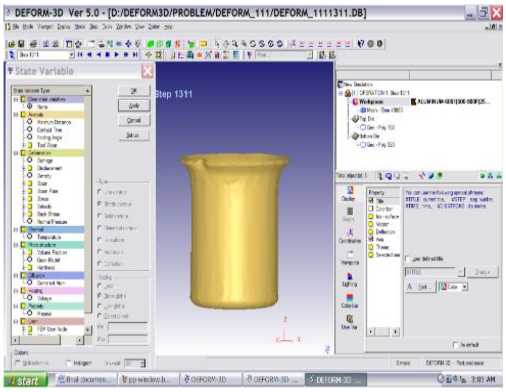


Fig 6: Post processor

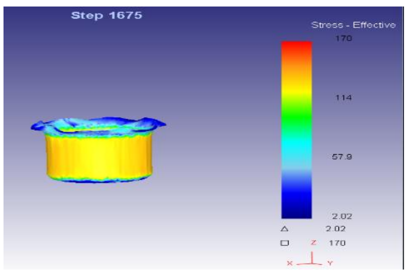


Fig7: stress values for the Aluminium plate of 1.50 mm

Table 2 - maximum and minimum strain values

Plate size	Maximum strain	Minimum strain
Thickness in 1.50 mm	9.69	0.0245

3.1 Experimentally Obtained Value For 1.50 Mm Plate 1

$Y= -128.04 X^2 + 1325.06 X - 74.941$……………………………….equation
Substituting the Multimeter readings in the equation
$Y= -128.04*(0.935)^2 +1325.6*(0.935) - 74.941$……………………..equation
Y= 1052.5 Kgf.,Total load = 1052.5*4;, Total load = 4210 Kgf
$Load_{Exp}$ = 4210 Kgf.
THEORETICALLY OBTAINED VALUE FOR 1.50 mm PLATE -Blank diameter (**d_0**) : 50 mm**,** Thickness of the plate : 1.50 mm, Ultimate tensile stress for Aluminium: 241 N / mm^2, From the Mechanical Metallurgy by George E. Dieter the formulae for the circular cup drawn is given by
$F = \pi d_0 t \sigma$
0…………………………………………………………………….equation
F = 3.14 * 50 * 1.50 *241.
F = 5675.5 Kgf.
Theoretical load is denoted by.
$Load_{Theo}$= 5675.5 Kgf.
The difference in between theoretical load and the experimental gives the deviation this is shown below.
Deviation = $Load_{Theo}$ - $Load_{Exp}$
Deviation = 5675.5 – 4210
Deviation = 1465.2
Percentage deviation = 1465.2 /**$Load_{Theo}$**
Percentage deviation = 25%.

Table [4]:- Comparison of the theoretical load and experimental load.

1	1.50	Aluminium	5675.5	4210.3	1465.2	25

4 EXPERIMENTAL DETERMINATION OF DRAWING FORCE 4

This output of the load cell is connected to the input of the charge amplifier by means of a special cable supplied with the charge amplifier. The output of the charge amplifier is connected to the input channel of the multi-meter

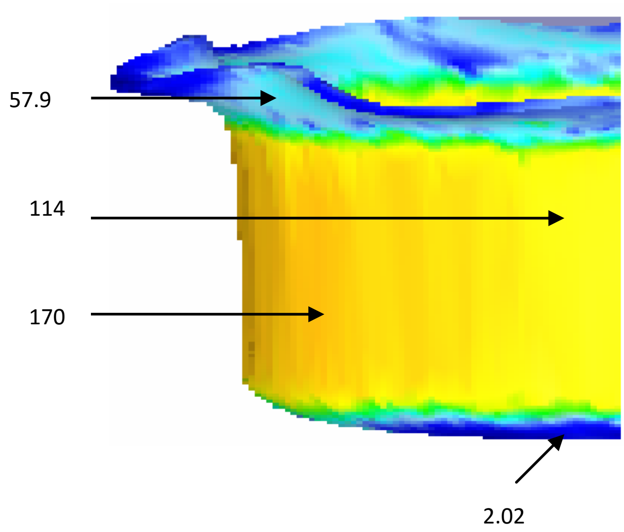
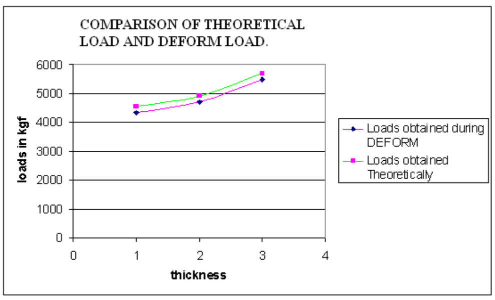


Figure 9:- comparison of theoretical load and the load obtained USING DEFORM.

Table4:- loads in theoretical as well as using DEFORM are in N/mm^2



The Empirical equation for the above curves is:

$$Y = 198.23 x^2 - 219.74x + 4347.3.$$

5 CONCLUSIONS

It is found that the maximum and minimum deviations of experimental values from theoretical values are:For Aluminium 17% minimum and 33% maximum deviations. This Errors or deviations are due to experimental errors and errors in material yield stress values.It is also observed that maximum stress occurs at maximum strain.The loads obtained using the deform package are slightly less than the load obtained theoretically (for 1.50 mm thick plate 5675.5 N/ mm^2 and 5471.2 N/ mm^2 using DEFORM package).The drawing forces using the DEFORM package and theoretical values are increasing with thickness .the Trend of the graph is curvilinear.An empirical equation obtained for both the curves is shown below.**$Y = 198.23 X^2 - 219.74 X + 4347.3$.**

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