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Prediction of Draw Ratio in Deep Drawing through Software Simulations

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Abstract:- Deep drawing process is one of the most commonly used Metal Forming Process within the industrial field. Different analytical, numerical, empirical and experimental methods have been developed in order to analyze it. In this paper deep drawing process with varying punch and die geometries are analysed. This work reports on the stages of finite element analysis (FEA) and simulations of a Deep drawing process. The obtained result allows to find optimum draw ratios in deep drawing.

Keywords:- Deep drawing, DEFORM-3D, Draw reduction ratio method, FEM simulation, LDR.

I. INTRODUCTION

The importance of sheet metal working process in modern technology is due to the ease with which metal may be formed into useful shapes by plastic stage deformation process in which the volume and mass of metal are conserved and metal is only displaced from one position to another. Deep drawing is one of the widely used sheet metal working process to produce cup shaped component at very high rate. The efficiency of deep drawing process depends upon many parameters and the choice of these parameters is very important to achieve the high drawability.

Deep drawing is a sheet metal forming process in which a sheet metal blank is vertically 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. This is achieved by redrawing the part through a series of dies. under plastic deformation material is deformed in to cup shape. The flange region (sheet metal in the die shoulder area) experiences a radial drawing stress and a tangential compressive stress due to the material retention property. These compressive stresses (hoop stresses) result in flange wrinkles (wrinkles of the first order). Wrinkles can be prevented by using a blank holder, the function of which is to facilitate controlled material flow into the die radius.

II. METHODOLOGY

Deep drawing can be done in single draw or multiple draws. When it is completed in multiple draws then, it is called re-drawing. Number of draws can be calculated by taking ratio of initial blank diameter to the required diameter of the cup which is known as Limiting Draw Ratio (LDR). In this paper three different blank are chosen with initial diameters 63, 94 and 132 and thickness 2mm.
Number of draws required for each blank is as follows:
63/20=3.15 (three draws (Three Stages) are required to get required shape)
94/30=3.13 (three draws are required to get required shape)
132/50=2.6 (three draws are required to get required shape)

There are two methods namely draw ratio and draw reduction ratio (DRR) method to calculate how much percentage should be drawn in each draw to get required dimensions of the part. In this analysis we have considered Draw Reduction Ratio method and in each draw the blank diameter may be calculated as follows:

$$\mathbf{DRR_1 = \frac{D-d_1}{D} = 45\% - 50\%}$$
$$\mathbf{DRR_2 = \frac{d_1-d_2}{d_1} = 30\% - 35\%}$$
$$\mathbf{DRR_3 = \frac{d_2-d_3}{d_2} = 20\% - 25\%}$$

D - Initial diameter of the blank
d_1, d_2, d_3, d_4. - Required punch diameter

Process simulation of deep drawing

The commercial FEA software DEFORM-3D™, a Lagrangian implicit code designed for metal forming processes, was used to model the DEEP DRAWING process. The use of an implicit code versus an explicit one is a sort of inescapable choice being the latter better united in order to correctly predict temperature evolutions and stress states.

DEFORM-3D 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. By simulating manufacturing processes on a computer, this advanced tool allows designers and engineers to:

1. Reduce the need for costly shop floor trials and redesign of tooling and processes.
2. Improve tool and die design to reduce production and material costs.
3. Shorten lead time in bringing a new product to market.

Initially the models of die and punch are generated using PRO/Engineer (CREO). Then these models are imported into DEFORM-3D where the sheet metal forming process is simulated. The material properties and process parameters used in this analysis are listed in below tables.

III. MATERIAL PROPERTIES

Material	Tensile strength (ultimate) N/mm^2	Tensile strength (yield) N/mm^2	Modulus of Elasticity
Stainless steel 304	821	407	200

IV. PROCESS PARAMETERS

Process parameters	value
Punch speed	2 mm/sec
Co-efficient of friction	0.12
Heat transfer coefficient (N/sec/mm/C)	5

V. RESULTS & DISCUSSION

In this paper production of three cups having inner diameter of 20mm, 30mm, 50mm and height of 46mm, 67mm ,74mm are chosen for analysis purpose. In order to produce a cup of the above dimensions the deep drawing process is to be repeated in 3-stages to get the final shape and size.

As per the theory [7] the blank diameters required in each stage are:
I Stage - punch diameter is 50% of the blank diameter.
II Stage - punch diameter is 30% of inner diameter of the cup drawn in stage I.
III Stage - punch diameter is 20% of inner diameter of the cup drawn in stage II.

For the three models under considerations the deep drawing process are simulated by varying the blank diameters until the final product is produced.

The results obtained are tabulated below:

Diameter	First Draw (50%)	Second draw (30%)	Second draw (25%)	Second draw (20%)	Third Draw (15-16%)
63	31.5 (success)	22 (failed)	23 (success)	25 (success)	20 (success)
94	47 (success)	33 (failed)	35 (failed)	37.6 (success)	32 (success)
132	66 (success)	46.2 (failed)	50 (failed)	53 (success)	50 (success)

Table 1: Results obtained from DEFORM 3D deep drawing process simulations

From the simulation results it is clear that, the success of deep drawing depends upon the punch diameter hence the values of punch diameter are very critical in deep drawing process.

First Stage

For the first draw the punch diameter is taken as 50% of initial blank diameter, because the maximum possible reduction in the first draw is 50% of the initial blank diameter. Fig (2), (7) and (13) shows the successfully drawn cups of three models.

Based on the theoretical approach called Draw Reduction Ratio method, the punch diameter in the first draw is to be reduced by 30% to perform the second draw. In software simulation performing the second draw with the theoretically calculated punch diameter the operation is getting failed. The failed components were shown in the Fig (3), (7), and (13).

Second Stage

On the trial and error base method the second draw was performed with two different sizes of punch diameter first punch diameter is reduced by 25% and second reduced by 20% .
From the results it is clear that the operation performed with the punch diameter25% is failed where as the punch diameter 20% has got successful result.

Hence it can be concluded that, the punch should be reduced by 20%-25% to perform the second draw, for successful completion of the process. Fig (4) , (10) and (16) shows the success fully drawn cups of three models.

Third Stage

As per the theoretical Draw Reduction Ratio method the punch diameter in the second draw is to be reduced by 20% to perform the third draw operation. But in DEFORM 3D it is found to that a reduction of 15%-16% of punch diameter of the second draw yields successful results. Fig – (5), (11) and (17) shows the successfully drawn cups of three models.

Figure (6), (12), and (18) shows the stress variations

Initial shape of Sheet (blank)

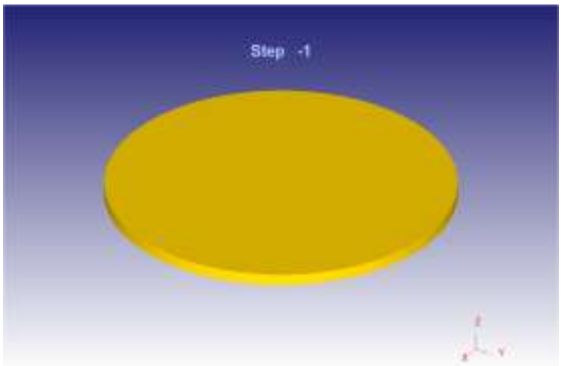


Figure.1

Initial blank (or) work piece of 63mm diameter

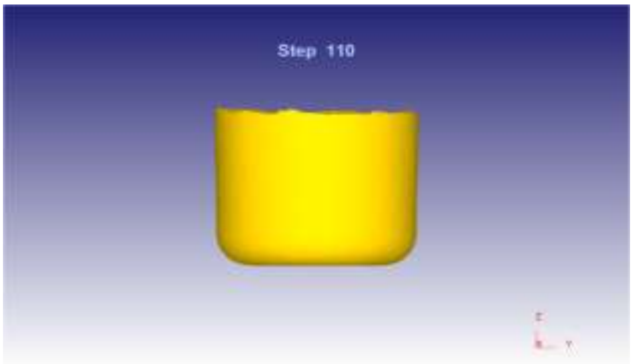


Figure.2

Draw 1

$DRR_1 = \frac{63-d_1}{63} = 50\% = d_1 = 31.5mm$

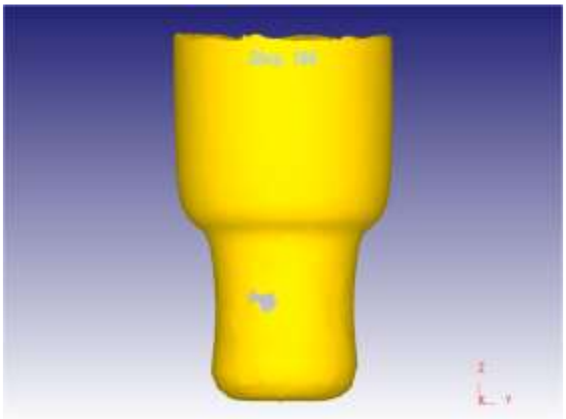


Figure.3

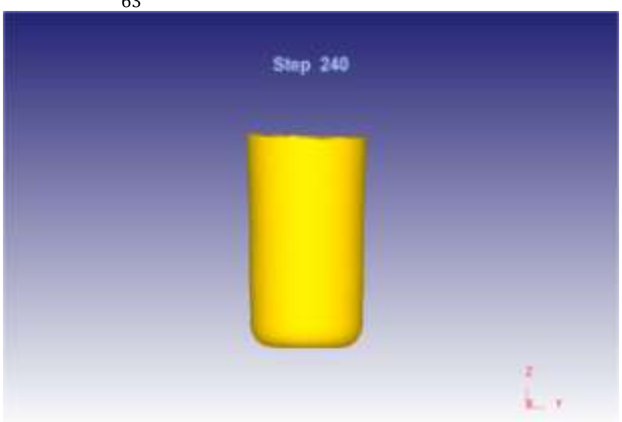
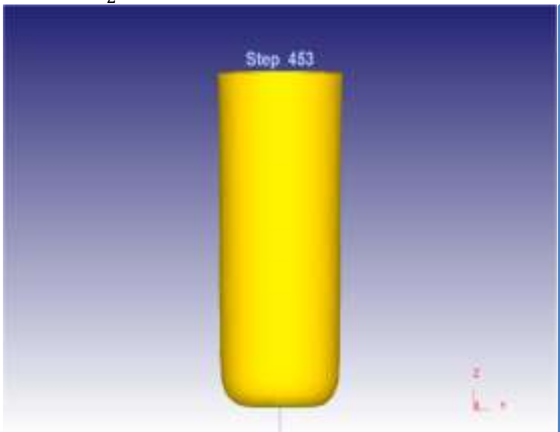


Figure.4

Draw-2 $DRR_2 = \frac{d_1 - d_2}{d_1} = 30\%$ $DRR_2 = \frac{d_1 - d_2}{d_1} = 25\%$

$d_2 = 22mm$ $d_2 = 23mm$



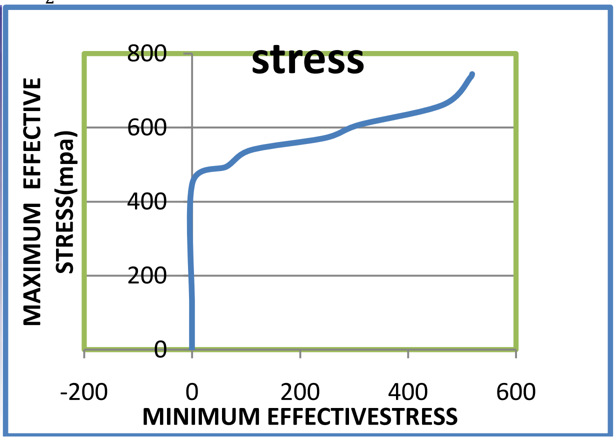
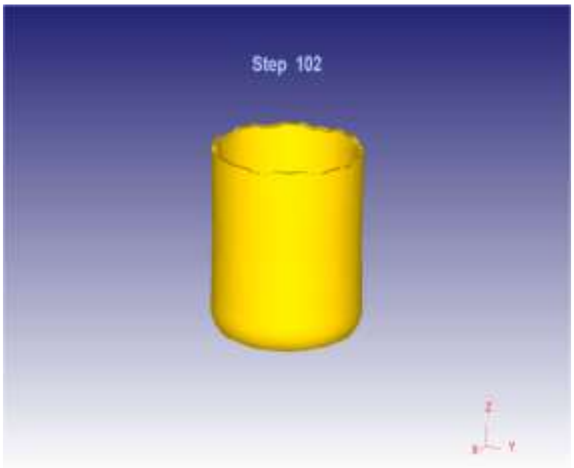


Figure.5 **Figure.6**

Required diameter 20mm can be drawn

Stress induced in forming process. because 15-16% is 19.3= 20mm.

For blank 94mm diameter



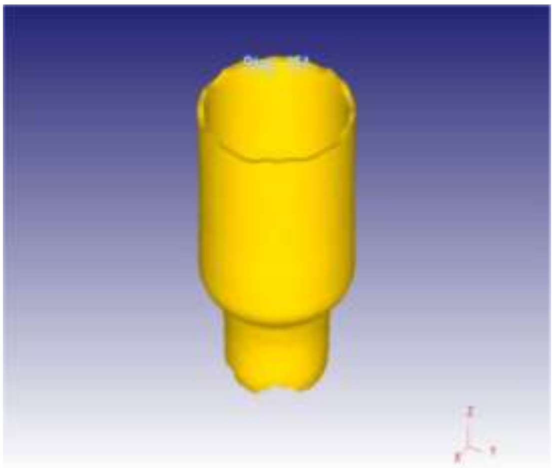


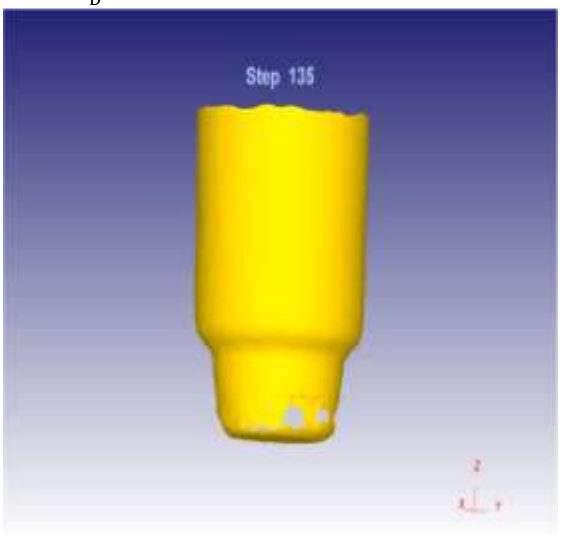
Figure.7 **Figure.8**

Draw-1

$DRR_1 = \frac{D - d_1}{D} = 45\% - 50\%$, d_1=47mm

Draw–2

$DRR_2 = \frac{d_1 - d_2}{d_1} = 30\%, d_2$ =33mm



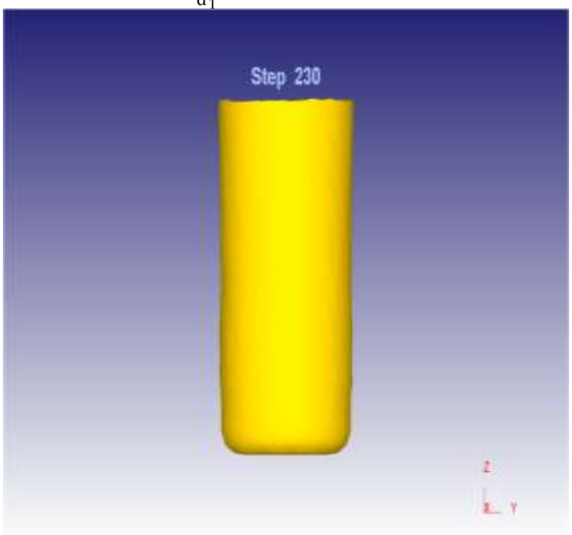
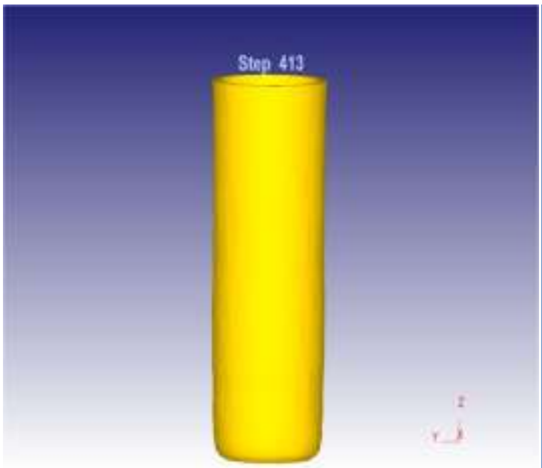


Figure.9 **Figure.10**

Draw – 2 $DRR_2 = \frac{d_1 - d_2}{d_1} = 25\%$ d_2 =35mm **Draw – 2** $DRR_2 = \frac{d_1 - d_2}{d_1} = 20\%$ $d_2 = 37.6mm$



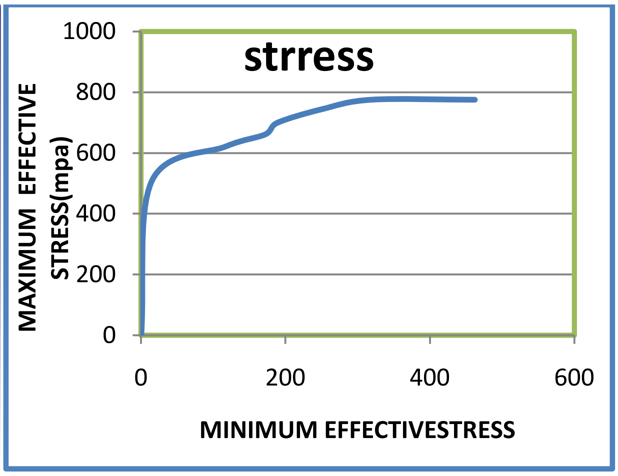
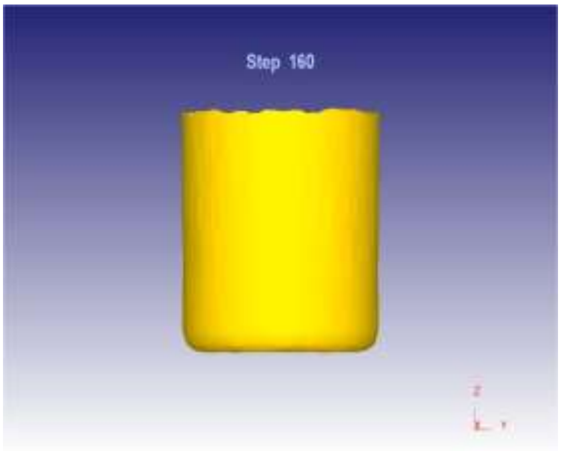


Figure.11
Draw-3 at 16%, d_3 =30mm
For blank 132mm diameter

Figure.12
Stress induced in forming process.



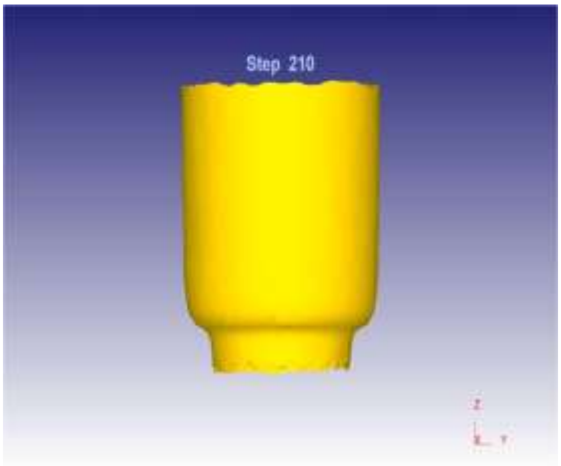


Figure.13
Draw – 1
$DRR_1 = \frac{D-d_1}{D} = 50\% \quad d_1 = 66mm$

Figure.14
Draw – 2
$DRR_2 = \frac{d_1-d_2}{d_1} = 30\% \quad d_2 = 46mm$

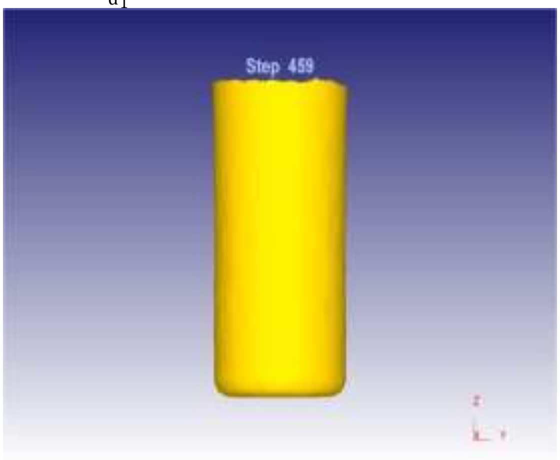


Figure.15
Draw – 2 $DRR_2 = \frac{d_1-d_2}{d_1} = 25\% \quad d_2 = 50mm$

Figure.16
Draw – 2 $DRR_2 = \frac{d_1-d_2}{d_1} = 20\% \quad d_2 = 53mm$

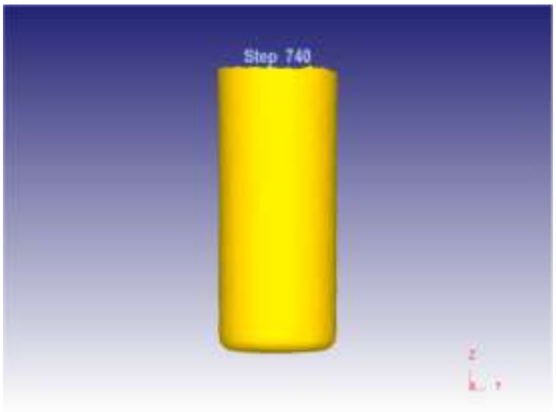


Figure.17

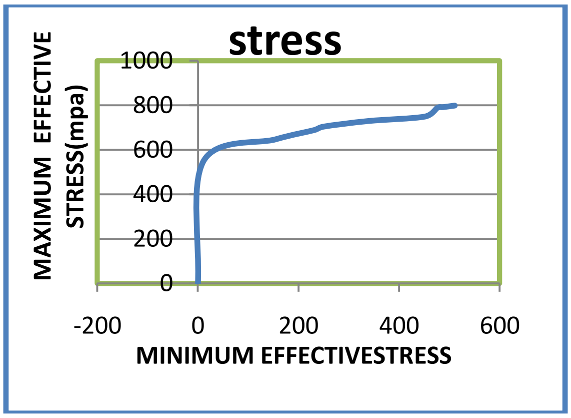


Figure.18

Draw – 3$DRR_3 = \frac{d_2 - d_3}{d_2} = 16\%$ required diameter Stress induced in forming process is 50mm so 50mm can be drawn.

For successful completion of deep drawing process the blank diameters required at three different stages are:

First Stage - Punch diameter is 50% of the blank diameter.

Second Stage - Punch diameter is 20%-25% of the internal diameter of the cup drawn in first stage.

Third Stage - Punch diameter is 15%-16% of the internal diameter of the cup drawn in Second Stage.

VI. CONCLUSION

As per the results this work concludes as below.

1) Drawing in stage one requires a blank diameter of 45%-50% for the process to be successful.
2) Redrawing in stage two requires 20%-25% of the blank diameter in stage one for successful draw.
3) In stage three requires 15%-16% of blank diameter in stage two for successful operation.

VII. FUTURE SCOPE

Further it can be extended to analyze plates with different thicknesses and materials.

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