Simulation Study of Warm Deep Drawing Process Using AFDEX Software

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Abstract — Deep drawing is one of the most widely used metal forming process to produce sheet metal parts especially in automobile industries. Warm working is the plastic deformation of metal at temperatures below the temperature range for recrystallization and above the room temperature. This project aims to study the behaviour of the material AZ31B under warm conditions. This project also aims to optimize the process parameters and design parameters. Designing/ modelling of dies and workpiece is carried out in SolidEdge V19. The simulation and analysis of this process is accomplished using AFDEX software. Initial temperature range is kept in between 250ºC-400ºC. With variable temperature, 7 iterations were performed and it was found that effective stress is minimum for temperature of 400ºC. 15 iterations were performed in AFDEX simulation software with variable die corner radius and co-efficient of friction to get optimized parameters. Punch velocity is kept at 300mm/s and binder holding force is kept at 730N. The results were tabulated for minimum damage vale, effective stress and effective strain.

Keywords: Warm Working, Solid Edge, AFDEX, AZ31B

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. This process is sometimes called drawing and is not to be confused with the bulk deformation process of drawing discussed earlier. A basic deep drawing operation could be the forming of a flat sheet into a three dimensional cup, or a box. The shape of a deep drawn part is not limited to a circle or square, more complex contours are possible. However, as the complexity goes up, the manufacturing difficulties increase rapidly. It is best to design the shape of a deep drawing to be as simple as possible. 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

II. LITERATURE SURVEY

N.Ethiraj, V.S.Senthilkumar[1] Experimental Investigation on Warm Deep Drawing of Stainless Steel AISI 304. In this investigation, 1.0mm thick circular specimen of stainless steel AISI 304 were warm deep drawn and the influence of temperature on the deformation behaviour of material and the drawing loads which is required to draw the component was studied. The results show that the warm working has positive effects like reduced drawing load, negligible amount of increase in thinning and thickening of a drawn component when compared to the conventional drawing and also there is no necking or cracking occurs due to the temperature influence.

Prof. A C Sekhara Reddy, Dr. S. Rajesham, Dr. P. Ravinder Reddy[2] Experimental Study on Strain Variation and Thickness Distribution in Deep Drawing of Axisymmetric Components. 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. 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.

SM Hussaini, Swadesh Kumar Singh, Amit KumarGupta[3] Formability studies of ASS 316 under different forming conditions. Deep drawing is one of the important sheet metal forming process to produce the complex shaped objects. Application of warm deep drawing is going to be most effective manufacturing process in industries. Present work is aimed to investigate the formability of austenitic stainless steel 316 in warm forming conditions and tried to find the best temperature to deep draw. Limiting drawing ratio and the thickness distribution of the drawn cup are the indicators of material formability in deep drawing. Finite Element analysis has been performed with the commercially available finite element software LS-Dyna at elevated temperatures. The simulations of deep drawing are compared and validated with the experimental data and found a good agreement between them. It is observed that formability of ASS316 increased up to 300°C, beyond this temperature, formability of this material is decreased. Based on the study, 300°C is found to be the best temperature to deep draw the ASS316.

Abhishek Kala1, V.B. Tungikar, Vishwanath P [4] The Effect of Process Parameters on Deep Drawing- A Review. In sheet metal parts deep drawing is one of the most important processes. For mass production of cup shapes in automobile, aerospace and packaging industries Deep drawing process is widely used. Deep drawing process is used to produce a light weight and high strength products. The quality of products is influenced by many of the process parameters like blank-holder force, blank shape, punch radius, die radius, material properties, and coefficient of friction, temperature etc. To produce product with minimum defects a good knowledge of process is required. Therefore, to avoid defects in the parts and to minimize production cost it is important to optimize the process parameters. Importance is given in this review paper to gather the recent research work and developments in the area of deep drawing.

III. SIMULATION

In this study simulation is carried out in AFDEX simulation software. AFDEX is user friendly and easy to use. Modeling of dies and workpieces is done in SolidEdge V19. Warm process is used to study the formability of the cup. Meshing is in auto configuration.

A. AFDEX (Adviser for Forging Design Expert)

AFDEX_V16 is general purpose metal forming simulation software that can be applied to conventional bulk metal forming processes and also to new creative bulk metal forming processes. Theoretically AFDEX is based on rigid-thermoviscoplastic finite element method.

B. Features of the software:

Pre-processor: The pre-processor assists and compile the input data for the simulation. In some of the cases, it helps the user to visualize and analyze the input data using the graphical user interface.

C. Post-processor:

The Post Processor is generally deployed to visualize and analysis the result. The stored result by the solver can be plotted graphically or in alphanumeric form by the post-processor.

Exclusive Forming Solver: The actual FEM based calculation is performed by the simulation engine or solver. Based on the input data, necessary formulations are initiated by the solver and the required calculations are performed sequentially

Material data base: Material property data for both work piece and die. The data should be sufficiently describing the behavior of the material, which it will reasonably experience during the entire deformation cycle.

IV. METHODOLOGY

In this study the nature of process is warm. In the warm deep drawing process the input temperature is in the range of 250ºC to 400ºC. Punch velocity is kept constant at 300mm/s and binder holding force is kept at 730N. For our study die corner radius and c0-efficient of friction is variable. The range of die corner radius is 3mm-7mm and co-efficient of friction is varied as 0.1µ, 0.15µ and 0.2µ. Deep drawing is a metal forming process in which a flat piece of sheet metal (i.e. blank) is transformed into a cylindrical form or shape. Such transformation can be produced either in a single stage or in a sequence of operations, which depends on the drawing ratio.

Component	Cup
Material Used	AZ31B
Forming Type	Warm
LDR	1.85
Meshing	Auto
Initial Billet Temperature	400ºC

Table 1: Details of the Component

A. Design of Dies

Fig 1 represents the design assembly of the cup. In deep drawing two upper dies and a lower die is needed to draw the cup. One of the upper die acts as binder which applies force on the workpiece in order to minimize wrinkling and tearing of the component.

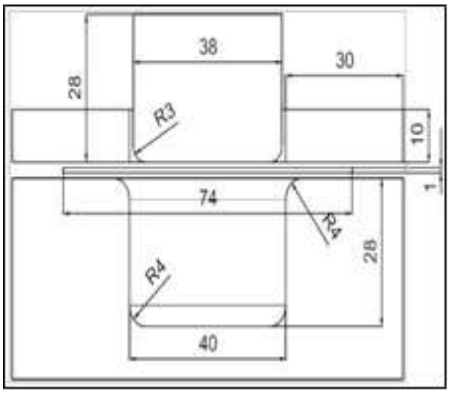


Fig 1: Design assembly of cup

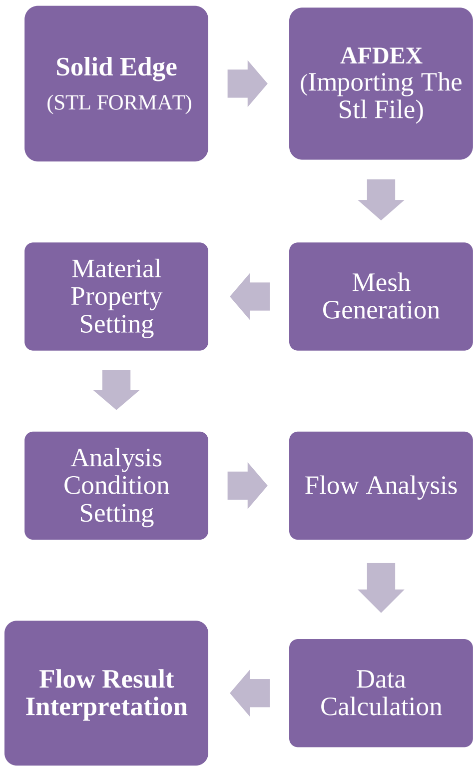
Component	Weight %
Magnesium	97
Aluminum	2.50 - 3.50
Zinc	0.60-1.40
Manganese	0.20
Silicon	0.10
Copper	0.050
Calcium	0.040
Iron	0.0050
Nickel	0.0050

Table 2: AZ31B Composition

Density	1.77 gm/cc
Tensile Yield Strength	200 MPa
Ultimate Tensile Strength	290 Mpa
Modulus of Elasticity	44.8 Gpa
Hardness – Brinell	49
Poisson's Ratio	0.35

Table 3: AZ31B Material Properties

The following flowchart shows the sequence of steps involved in executing the simulations in the present study



V. RESULTS

7 simulations were carried out in AFDEX software by changing the initial temperature value. The range of temperature is from 250ºC to 400ºC. All other parameters were kept constant. Results were analyzed for effective stress values and tabulated as shown in table 4.

SL. NO.	Temperature (ºC)	Effective Stress (N/mm^2)	Damage Value
1	250	2.72086E+002	3.31428E-001
2	275	2.13550E+002	3.15501E-001
3	300	1.77739E+002	2.99090E-001
4	325	1.37773E+002	3.05081E-001
5	350	9.71394E+001	3.17941E-001
6	375	9.67598E+001	2.98685E-001
7	400	9.54321E+001	3.18879E-001

Table 4: Effective Stress values

15 simulations are carried out in AFDEX simulation software. Results are analyzed for minimum damage value and are tabulated as shown in table 5.

SL. NO.	Co-efficient of Friction (μ)	Die Corner Radius (mm)	Damage Value
1	0.1	3	4.60805E-001
2		4	3.61239E-001
3		5	3.11123E-001
4		6	2.84963E-001
5		7	2.77302E-001
6	0.15	3	4.95059E-001
7		4	3.73092E-001
8		5	3.23637E-001
9		6	2.91108E-001
10		7	2.67362E-001
11	0.2	3	5.19953E-001
12		4	3.73403E-001
13		5	3.20484E-001
14		6	2.93779E-001
15		7	2.72335E-001

Table 5: Damage values

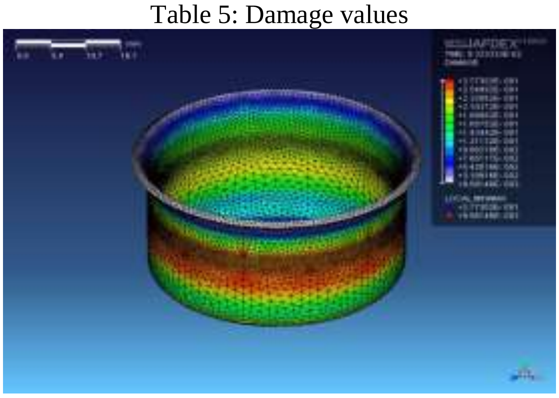


Fig 2: Damage value of cup drawn with Co-efficient of friction 0.1 and die corner radius 7mm.

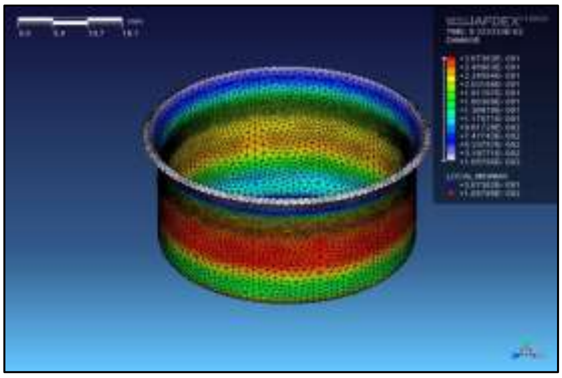


Fig. 3: Damage value of cup drawn with Co-efficient of friction 0.15 and die corner radius 7mm.

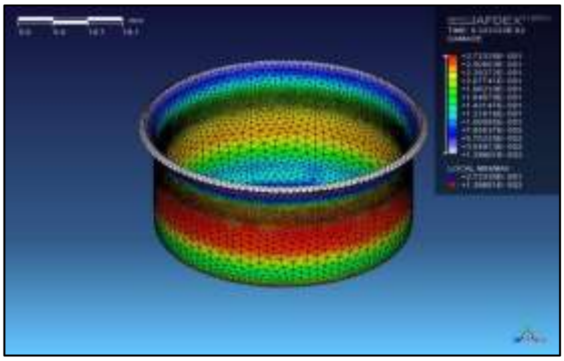


Fig. 4: Damage value of cup drawn with Co-efficient of friction 0.2 and die corner radius 7mm.

VI. CONCLUSIONS

Seven iterations were performed with variable initial temperature only and fifteen iterations were carried out using different values of the parameters which consist of variable die corner radius and co-efficient of friction in the AFDEX software and the results were obtained. BHF and punch velocity were kept constant.

In case of variable temperature we can observe that an increase in the value of initial temperature leads to decrease in the value of effective stress generated in the deep drawn cup. Effective stress was minimum for initial temperature value of 400ºC. We can conclude that a rise in temperature will increase the formability of the cup.

From the table 5, we can observe the damage value obtained is minimum in the 10th iteration (Co-efficient of friction = 0.15 and die corner radius = 7mm).

- For the value of die corner radius = 7mm and Co-efficient of friction = 0.15, the corresponding damage value was 2.67362E-001. And the following parameters were used in the analysis of this iteration,
- BHF = 730N
- Ram Velocity = 300 mm/sec
- Friction co-efficient = 0.15
- Temperature = 400ºC

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,

- Increase in the initial temperature value tends to decrease the effective stress generated in the component and hence the formability also increases.
- Co-efficient of friction is one of the most important parameter in deep drawing process. The damage value is minimum for value 0.15. As the value of coefficient of friction increases there is corresponding increase in damage value.
- As the value of die corner radius increases the corresponding damage value tends to decrease. Hence the wrinkling and tearing effect minimizes. The damage value is minimum for the die corner radius 7mm.
- 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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