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STUDY AND PROCESS PARAMETERS OPTIMIZATION ON THE CUP DRAWING OF ALUMINIUM 3003 SHEET USING CENTRAL COMPOSITE DESIGN

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Abstract
The present project work analyses different parameters of drawing operation to minimize the defects. Drawing operation is usually applied for component made of aluminium. Good surface finish with required tolerances and dimensional accuracy can be achieved by optimization of controllable process parameters such as blank holding force, lubrication and punch speed. Moreover, by selection of optimum process parameters the press forming defects such as crack, wrinkles, surface defects, breakage, and tolerance errors etc. are also minimized. Therefore, a drawing component, Aluminium blank (3003 H14) has been considered. The effects of selected process parameters on drawing defects and subsequent setting of parameters with the levels have been accomplished by using central composite design. Numerical simulations were conducted using the finite element method using DEFORD 3D. Damage value is obtained for entire cup. The results obtained from this numerical analysis are compared with experimental results.

Index terms: DEFORD 3D

1. Introduction
In sheet metal forming, a thin blank sheet is subjected to plastic deformation using forming tools to conform to a designed shape. During this process, the blank sheet is likely to develop defects if the process parameters are not selected properly. Therefore, it is important to optimize the process parameters to avoid defects in the parts and to minimize production cost. Optimization of the process parameters such as punch speed, cushioning pressure, friction coefficient, etc., can be accomplished based on their degree of importance on the sheet metal forming characteristics. In this investigation, a statistical approach based on central composite design was adopted to determine the degree of importance of each of the process parameters on the damage value of deep drawn circular cup. CCD has been applied in forming studies to design the experiments and determine the influence of process parameters on characteristics of the formed part.

Deep Drawing Process
As mentioned in the introduction chapter, flat sheet of metal is formed into a 3-d product by deep Drawing process. The main tools of the process are blank, punch, die and blank holder. In the simple circular cup drawing process with blank holder, the tools and tool geometries are shown in the Figure 1.

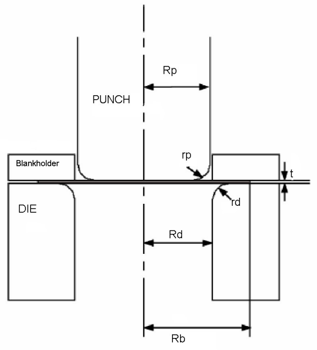

Fig 1. Geometry parameters for deep drawing tools

The tool geometry parameters are stated as;
- Punch Radius (Rp) = 160 mm
- Punch Edge Radius (rp) = 12 mm
- Blank Thickness (t) = 3mm
- Blank Radius (Rb)= 300 mm
- Die Radius (Rd)= 166.2 mm
- Die Edge Radius (rd)= 18 mm

These parameters must be measured very carefully because the final product highly depends on these geometries. Shape of the fully drawn cup is obtained by selecting die and punch respectively.

2.1 Materials
The work piece materials chosen for this study are aluminium alloys AA3003 H14, the composition and property of aluminium alloys are given in
Table-1

Table 1 Composition of aluminium alloy AA3003 H14

S.no	Element	Amount (Wt%)
1	Aluminium(Al)	96.7-99
2	copper (Cu)	0.005-0.2
3	iron (Fe)	0.7
4	manganese (Mn)	1.5
5	silicon (Si)	0.6
6	zinc (Zn)	0.1

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Table 2 Properties of Aluminium alloy AA3003 H14

S.no	Physical properties	value
1		2.73 g/cm^3
2		69 Gpa
3	Electrical Conductivity	41 % IACS
4		61.2 Mba
5	Brinell Hardness	40
6	Melting Temperature	643 °C
7		0.33
8	Shear Strength	97 Mpa
9	Ultimate Strength	150 Mpa
10	Thermal	159 W/m-K
11	conductiviy	23.2 µm/m-K

Central composite designs

There are Central Composite designs for any number of factors, but we will focus on the three factor case. The graphic shows the design as a pattern of points in a coded three-dimensional factor space.

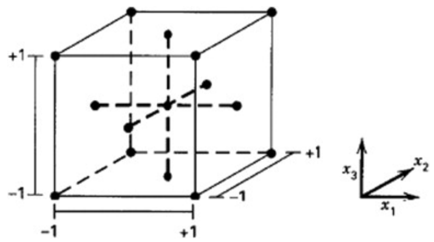

Fig 2. Central composite design

The design is called composite because it can be thought of as the union of three separate pieces:

• The eight corners of the cube, which form a two level full factorial

• The six points in the centers of each face, known as the axial points or the star points

• The centre point.

Table 3 Parameters and their levels studied in the experiments

S.no	Parameter	Range		Unit
		Maximum	Minimum	
1	Punch speed	120	140	KN
2	Cushioning pressure	2	4	Kg/cm^2
3	lubrication	8	15	ml

After defining levels of effective factors, the designing of experiments by central composite design can be done. In this project work, the design of experiments is created by MINITAB statistical software. Results of CCD for this work are shown in Table.

Results of central composite design (CCD).

Factors: 3 Replicates: 1
Base runs: 20 Total runs: 20
Base blocks: 1 Total blocks:

3. Numerical Simulation And Experimentation

Numerical simulations of the process were conducted in FEA software: DEFORM 3D. The configuration of the punch, die, blank and blank holder modeled in the software is shown in Fig.No.3.. Deep drawing quality aluminum sheet (IS 573:1994) [13] of initial thickness 3 mm was used as blank material. Results obtained from FEA were damage value by varying different parameter levels. Experiments were carried out with initial blanks of size Ø 300 mm. To obtain the percentage of damage area was measured at various locations.

Numerical simulation;

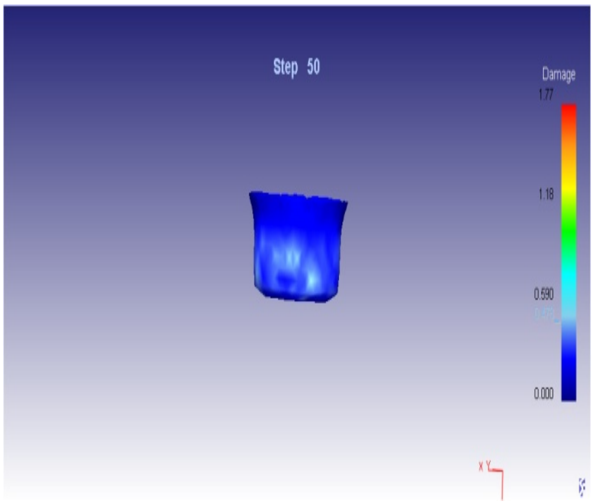

Fig 5. Sample simulation result

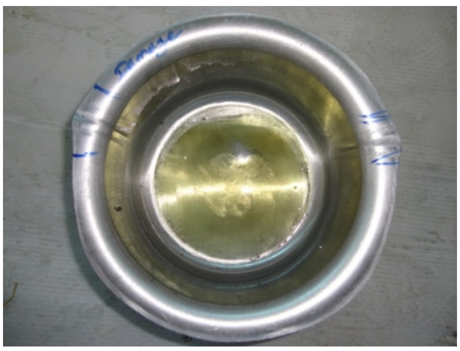

Fig 8. Aluminium 3003 cup sample

Table 4
DOE based on central composite design. and experimental result

Run Order	simulation parameters			Experiment parameters			Experimen t result	FEA result
	Punch speed	BH pressure	friction co efficient	Punch speed	BH pressure	amount of lubrication	% of damage area	Damage
1	130	3	0.01	130	3	8.4	1.801	1.31
2	130	3	0.015	130	3	14.3	0.797	0.379
3	140	2	0.02	140	2	20.2	1.941	0.478
4	140	4	0.01	140	4	8.4	1.234	0.621
5	130	4	0.015	130	4	14.3	0.721	0.671
6	130	3	0.02	130	3	20.2	2.511	0.376
7	130	3	0.015	130	3	14.3	0.871	0.379
8	140	2	0.01	140	2	8.4	2.24	0.401
9	120	3	0.015	120	3	14.3	6.00	0.615
10	140	4	0.02	140	4	20.2	0.589	0.478
11	120	4	0.02	120	4	20.2	4.572	1.08
12	120	4	0.01	120	4	8.4	6.832	0.406
13	130	3	0.015	130	3	14.3	0.871	0.379
14	130	2	0.015	130	2	14.3	0.174	0.471
15	130	3	0.015	130	3	14.3	0.871	0.379
16	130	3	0.015	130	3	14.3	0.871	0.379
17	120	2	0.01	120	2	8.4	3.945	0.681
18	130	3	0.015	130	3	14.3	3.396	0.379
19	140	3	0.015	140	3	14.3	1.087	1.35
20	120	2	0.02	120	2	20.2	3.371	1.04

4. Result and discussion

Simulation based results:

In the engineering experiments, general aim is to determine the conditions that can lead to optimum results. The optimum result could be either a maximum or a minimum of a function of the design parameters. One of methodologies for obtaining the optimum result is response surface method (RSM). In most RSM problems, there is a functional relation between responses and independent variables and this relation can be explained using the model below.

$$\eta = \beta 0 + \sum_{i-1}^{k} \beta i X_i + \sum_{i-1}^{k} \beta_{ij} X^2 \sum_{i} \sum_{j} \beta\beta_{ij} X_i X_j + \varepsilon \quad (1)$$

Where η is the estimated response (surface roughness), β_0 is constant, β_i, β_{ii} and β_{ij} represent the coefficients of linear, quadratic and cross-product terms, respectively. X reveals the coded variables that correspond to the studied parameters such as Punch speed (s), Blank holding pressure (p) and Friction co efficient (μ). The relationship between the surface roughness and drawing parameters are expressed as follows

$$Ra=\beta_0+\beta_1(s)+\beta_2(P)+\beta_3(\mu)+\beta_4(s_2)+\beta_5(p_2)+\beta_6(\mu_2)+\beta_7(S_P)+\beta 8(S\mu)+\beta_9(P\mu) \quad (2)$$

The tests for significance of the regression and individual model coefficients were performed to verify the goodness of fit for the obtained model. The analysis of variance (ANOVA) was applied to summaries these tests. Additionally, plot of main effects, interactions, normal probability and 3D response surface corresponding to each ANOVA analysis were constructed.

Response Surface Regression: damage versus punch speed, blank holding pressure, friction co efficient

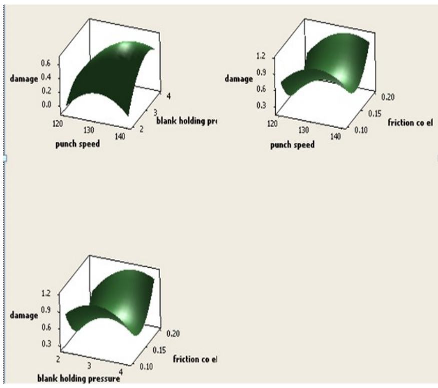

Fig 3D Surface plot for damage

The analysis was done using coded units. The linear s,p,μ quadratic s2, p2 and μ2 and interactive s×p,p×μ, μ × s , factors that can affect the surface roughness parameter (Ra), the arithmetic mean of absolute roughness are given in Table 5.

The most significant factor on the parameters Ra is friction co efficient (μ), which explains 83.4% contribution of total variation. The next contribution on Ra comes from the approach blank holding pressure (p) and punch speed (s) with the contributions 18.4% and 6.7%, respectively.

Table 5
Estimated Regression Coefficients for damage

Term	Coef	SECoef	T	P
Constant	0.63774	0.08265	7.716	0.000
punch speed	0.15620	0.07603	2.055	0.067
blank holding pressure	0.10840	0.07603	1.426	0.184
friction co efficient	0.01650	0.07603	0.217	0.833
punch speed*punch speed	-0.26559	0.14498	-1.832	0.097
blank holding pressure* blank holding pressure	-0.26559	0.14498	-1.832	0.097
friction co efficient* friction co efficient	0.48091	0.14498	3.317	0.008

Table 6
Analysis of Variance for damage

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Regression	9	1.3885	1.3885	0.15428	2.67	0.071
Linear	3	0.3642	0.3642	0.12140	2.10	0.164
Square	3	0.7523	0.7523	0.25076	4.34	0.033
Interaction	3	0.2720	0.2720	0.09068	1.57	0.258
Residual Error	10	0.5780	0.5780	0.05780		
Lack-of-Fit	5	0.2278	0.2278	0.04556	0.65	0.676
Pure Error	5	0.3502	0.3502	0.07004		
Total	19	1.9666				

Table 7
Estimated Regression Coefficients for damage using data in uncoded units

Term	Coefficient
Constant	-36.2954
punch speed(S)	0.649156
blank holding pressure (P)	-0.404055
friction co efficient (μ)	-78.1141
punch speed*punch speed	-0.00265591
blank holding pressure* blank holding pressure	-0.265591
friction co efficient* friction co efficient	192.364
punch speed*blank holding pressure	0.0136125
punch speed*friction co efficient	0.107750
blank holding pressure* friction co efficient	2.24250

Surface roughness quadratic model

Estimated regression coefficients for surface roughness using data in unicoded units are shown in Table 6. The quadratic model of response equation in terms of actual factors for surface roughness (Ra) is

$$Ra = -36.2954 + 0.649156\,S - 0.404055\,p - 78.1041\,\mu - 0.00265591\,S^2 - 0.265591P^2 + 192.364\mu^2 + 0.0136125$$

$$sp + 0.107750\,s\mu + 2024250\,p\mu \text{ ---------(3)}$$

The empirical Eq. (3) shows greater agreement than 96% in the fit values. Hence, these equations can be used for determining the damage factor in drawing operation.

5. Conclusion

In this paper, the simulation of aluminum 3003 cup was carried out by using DEFORM 3D and experiment was conducted in 400T hydraulic press. In addition, a quadratic model is developed for the damage factor (Ra) so as to investigate the influence of drawingprocess. The simulation results of the research are as follows

1. The result of ANOVA proved that the quadratic mathematical models allow prediction of damage factor with a 96% confident interval.
2. Friction co efficient is the most significant factor on damage factor with 83.4% contribution in the total variability of model. The quadratic effect of friction co efficient little provides little contribution to the model.
3. Also, punch speed and blank holding pressure age significant factors on damage factor with 18.4% and 6.74% contribution in the total variability of model, respectively.
4. It can be said that the interaction between all factors has no significant effect on damage factor.

6. Further work

The future work of the project work involves the analyzing the results of experimental model carried using 400T hydraulic press. Finally compare the simulation results with experimental results. Such a comparison will help us understanding the simulation results over the experimental model.

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