OPTIMIZATION OF TOOL PARAMETER AND PROCESS PARAMETER TO REDUCE WRINKLES AND THINNING FOR DIFFERENT SHEET THICKNESSES

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Abstract

Prediction of the forming results, determination of the thickness distribution and the thinning of the sheet metal blank will decrease the production cost through saving material and production time**.** During the product design and tool design designer are still adapts trial and error method to decide blank shape, blank size, draw tool and process parameters. Computer aided engineering (CAE) plays very significant role in the decision making of various parameters of sheet metal forming processes and it helps to designer during product design as well tool design stage to decide optimum and accurate process parameters. It is described the study of effect of die parameter such as die radius and process parameters such as blank holding force for different thicknesses on defects like wrinkles and thinning during sheet metal single stage drawing of cylindrical cup. The result of Altair HyperForm well matches with the actual produced products

Keywords: Blank Holding Force, Friction, Optimization

Introduction:

Metal forming involves plastically deforming a piece of material to obtain the desired product. A special class of metal forming where thickness of the work piece is small compared to the other dimension is called sheet metal forming. It is the process of converting a flat sheet metal into a part of desired shape without defects (fracture or excessive thinning, wrinkling etc.). Formability is the ability of a sheet metal to be formed without failure. Sheet metal forming is a significant manufacturing process for producing a large variety of automotive parts, aerospace components as well as consumer products (kitchen sinks, cans, boxes, etc.). These are broadly classified as forming/drawing/ stamping and deep drawing operations, which include a wide spectrum of operations and flow conditions. Deep drawing is a compression-tension forming process. The sheet material is subject to a large plastic deformation combined with a complex flow of material. Design in sheet metal forming, even after many years of practice, still remains more an art than science. This is due to the large number of parameters involved and their interdependence. These are material properties, machine parameters such as tool and die geometry, work piece geometry and working conditions. Research and development in sheet metal forming processes requires lengthy and expensive prototype testing and experimentation in arriving at a competitive product.

The main phenomena of instability appearing at the cold forming of metal sheets, which lead to a decrease of the processing accuracy through the modification of the geometrical shape and the faulting of the machined surfaces, can be thus grouped: Phenomena of instability which appear after the process of plastic deformation and which lead the modification of the shape of the deformed parts after the deformation forces have stopped. The most important phenomenon of this kind is the phenomenon of elastic recovery

Blank Holder Force (BHF)

Control of the blank holding force enables control of friction on the flange during deep drawing process. It is used to contain the formation of wrinkles that can appear in the component flange. When higher the BHF, stress normal to the thickness more which restrains any formation of wrinkles. in order to have less thinning in the component, the maximum punch force must be reduced. This can be getting by controlling the BHF throughout the process. BHF is small at beginning, which is good for the flow of material towards die cavity. Increase in blank holder force reduces sliding of the sheet between the die and the binder and reduces spring back by increasing the tension

B. Radius on Die (RD)

Theoretically, the radius on the die should be as large as possible to permit complete metal flow as it passes over the radius. The die radius causes the metal to begin flowing plastically and side in compressing and thick the outer portion of the blank. If the draw radius is too large, the metal will be release by the blank holder too soon and causes wrinkling.

Radius on Punch (RP)

here is no rule for the size of the radius on the punch. A sharper radius can require greater forces when the metal is folded in the region of the punch nose and may result in uncontrollable thinning or fracture, tearing at the bottom of the cup component. A common rule to reduce the thinning is to design the punch radius of from 4-8 times the thickness of metal. It has been seen that the die and punch radii have the more effect on the thickness of the deformed mild steel cups compared to blank -holder force or friction

Coefficient of Friction (μ)

In metal forming processes friction influences the strain distribution at blank - tool interface and draw ability of metal sheet. The force of friction between the work piece blank and surfaces of die must be overcome in a deep drawing operation. The force of the blank holder adds significantly to the force of static friction.

Literature review:

Cao and Boyce [1] built upon this work to develop a novel approach to determine a variable BHF trajectory. The authors performed finite element simulations with PI control of the blank holder force. They were able to calculate a BHF trajectory having a combined upward and downward portion that showed a 16% increase in forming height over the results obtained by the best constant binder force case.

Neugebauer et al [2] performed studies using flexible binders and multiple draw pins. Their experimental set up consisted of an asymmetric part and a binder which had 12 draw pins distributed evenly along its periphery. The draw pins could be used to apply different values of binder force. They studied four cases, a rigid binder ~80 mm thick! with a uniform pin force, a rigid binder with a non-uniform pin force, a flexible binder ~30 mm thick! with a uniform pin force and a flexible binder with a non-uniform pin force

Doege et al. [3] proposed an innovative concept in which the blank holder is designed as an elastically deformable thin steel plate. The authors used FEM analysis to determine the plate thickness and the location of support elements holding the binder. They performed experiments at various binder force values to estimate a „„safe working area.‟‟ The authors were able to show that the safe working area for a part is larger with a pliable blank holder and it moves towards higher blank holder force values. Furthermore, it was shown that the distribution of pressure on the blank was more uniform, thus giving rise to improved part quality

Fenn and Hardt [4] developed a real-time closed-loop control system to alter the binder force during the forming process using the actual punch force or material draw-in as inputs. They obtained consistent forming heights despite the presence of variations in the lubricant, blank location and initial binder force

Equipment and Tool Set-up:

Deep drawing experiments were carried out on a 125 metric ton capacity hydraulic press. Experimental setup is shown. The punch has an outer diameter of 57.5 mm whilist the die ring has an outer diameter of 115 mm, an inner diameter of 59.7 mm and 40 mm in height. So upper limit of drawing ratio's was reached as 2.0

Mathematical Draw calculations:

Given data:-

1) Draw perimeter = 1995 mm
2) Draw height (h) = 71 mm
3) Draw constant (K) = 0.6-0.7

Calculation of punch diameter (d) in mm

Punch diameter (d) = Punch perimeter/π = 1995/π = 635 mm

Calculation of h/d ratio to find number of draw required:

Here, h/d = 0.111 0 < h/d < 0.75- Simple draw 0.75 < h/d < 1.5 - Deep draw Hence simple draw is required for complete forming of REINF-RR END UPR-LH/RH

Calculation of blank diameter (D):

D = √ d 2 + 4dh = √ 6352 + 4×635×71 = 764 mm

Calculation of draw force (F)

F = πdtσy [D / d – K] = 3.14 × 635 × 0.65 × 220 × [764 / 635 – 0.65] = 157798 N = 16 Ton

Blank holder load (BHL)

BHL = 20% of draw force (F) = 3.2 Ton

Draw Tonnage (P) = F + BHL
= 16+ 3.2
= 19.2 Ton

Factors influencing % thinning & their values

Factors influencing % thinning	Levels		
	Level 1	Level 2	Level 3
Blank holding force	20	28	60
Draw bead height	0	5	6
Binder stroke	85	90	95

L9-OA was constructed based on Taguchi method to evaluate the significance of interaction term.

L9- orthogonal array

Sr. No	BHF	DBH	BS
1	2	0	89
2	2	5	93
3	2	6	95
4	4	0	90
5	4	5	95
6	4	6	85
7	6	0	95

8	**6**	**5**	**85**
9	**6**	**6**	**90**

Results and discussions:

Result of 27 experiments, which are taking on different process parameter i.e. Different Die entry radius and BHF at different blank thickness by software are as follows.

Result of virtual experiments.

Ex. No.	Dr (mm)	BHF (N)	Thk (t)	Thinning %		P- Q	Thickness		R- S	wrinkles
				Max (P)	Min (Q)		Max (R)	Min. (S)		
1	2	1000	0.5	44.83	-130.9	175.73	1.154	0.276	0.878	Yes
2	2	1200	0.5	24.32	-79.47	103.79	0.897	0.378	0.519	Yes
3	2	1400	0.5	24.59	-75.71	100.3	0.879	0.377	0.502	Yes
4	2	1000	0.75	29.44	-36.42	65.86	1.023	0.529	0.494	Yes
5	2	1200	0.75	31.81	-44.78	76.59	1.086	0.511	0.575	Yes
6	2	1400	0.75	28.81	-39.30	68.11	1.045	0.591	0.454	Yes
7	2	1000	1	30.92	-34.69	67.61	1.347	0.691	0.656	Yes
8	2	1200	1	33.23	-22.61	55.84	1.226	0.668	0.558	Yes
9	2	1400	1	22.03	-17.16	39.19	1.246	0.641	0.605	Yes
10	4	1000	0.5	19.12	-40.66	59.78	.7218	.4043	0.318	Yes
11	4	1200	0.5	28.15	-17.02	45.17	0.565	.3593	0.206	No
12	4	1400	0.5	27.79	-17.02	44.81	.585	.3611	0.224	Less
13	4	1000	0.75	22.95	-22.84	45.79	.9213	.5779	0.344	Yes
14	4	1200	0.75	24.97	-12.47	37.44	.8435	.5624	0.281	No
15	4	1400	0.75	25.06	-12.60	37.66	0.844	.562	0.282	No
16	4	1000	1	21.93	-24.59	46.52	1.246	.7807	0.465	Yes
17	4	1200	1	22.03	-17.16	39.19	1.172	.7797	0.392	Less
18	4	1400	1	22.4	-12.51	34.91	1.125	.7756	0.349	No

19	6	1000	0.5	18.98	-44.95	63.93	0.725	0.405	0.320	Yes
20	6	1200	0.5	22.72	-40.99	63.71	0.705	0.386	0.319	Yes
21	6	1400	0.5	22.87	-96.24	119.11	.981	0.386	0.595	Yes
22	6	1000	0.75	25.10	-21.99	47.09	0.915	0.562	0.353	yes
23	6	1200	0.75	26.31	-12.62	38.93	0.845	0.553	0.292	less
24	6	1400	0.75	26.71	-12.28	38.99	0.842	0.550	0.292	No
25	6	1000	1	23.94	-11.89	35.83	1.119	0.761	0.358	No
26	6	1200	1	24.08	-11.93	36.01	1.119	0.759	0.358	No
27	6	1400	1	23.81	-11.90	35.71	1.119	0.762	0.357	No

Taguchi Analysis: Pm versus DIE RAIUS, BHF, BT

Linear Model Analysis: SN ratios versus DIE RAIUS, BHF, BT

Estimated Model Coefficients for SN ratios

Term Coef SECoef T P
Constant -28.4601 0.7200 -39.530 0.001
DIE RAIU 2 -1.5209 1.0182 -1.494 0.274
DIE RAIU 4 0.8088 1.0182 0.794 0.510
BHF 1000 -0.8164 1.0182 -0.802 0.507
BHF 1200 0.4468 1.0182 0.439 0.704
BT 0.50 -1.2190 1.0182 -1.197 0.354
BT 0.75 -0.1400 1.0182 -0.138 0.903

S = 2.160 R-Sq = 71.6% R-Sq(adj) = 0.0%

Analysis of Variance for SN ratios
Source DF Seq SS Adj SS Adj MS F P
DIE RAIUS 2 10.423 10.423 5.212 1.12 0.472
BHF 2 3.008 3.008 1.504 0.32 0.756
BT 2 10.058 10.058 5.029 1.08 0.481
Residual Error 2 9.330 9.330 4.665
Total 8 32.820

Linear Model Analysis: Means versus DIE RAIUS, BHF, BT

Estimated Model Coefficients for Means
Term Coef SECoef T P
Constant 27.2011 2.510 10.836 0.008
DIE RAIU 2 5.6889 3.550 1.603 0.250
DIE RAIU 4 -2.9444 3.550 -0.829 0.494
BHF 1000 3.3722 3.550 0.950 0.442
BHF 1200 -1.6811 3.550 -0.474 0.682
BT 0.50 4.5789 3.550 1.290 0.326
BT 0.75 -0.0444 3.550 -0.013 0.991
S = 7.531 R-Sq = 73.9% R-Sq(adj) = 0.0%
Analysis of Variance for Means

Source DF Seq SS Adj SS Adj MS
F P
DIE RAIUS 2 145.70 145.70 72.85
1.28 0.438
BHF 2 51.17 51.17 25.59 0.45
0.689
BT 2 124.59 124.59 62.29 1.10
0.477
Residual Error 2 113.42 113.42 56.71
Total 8 434.88

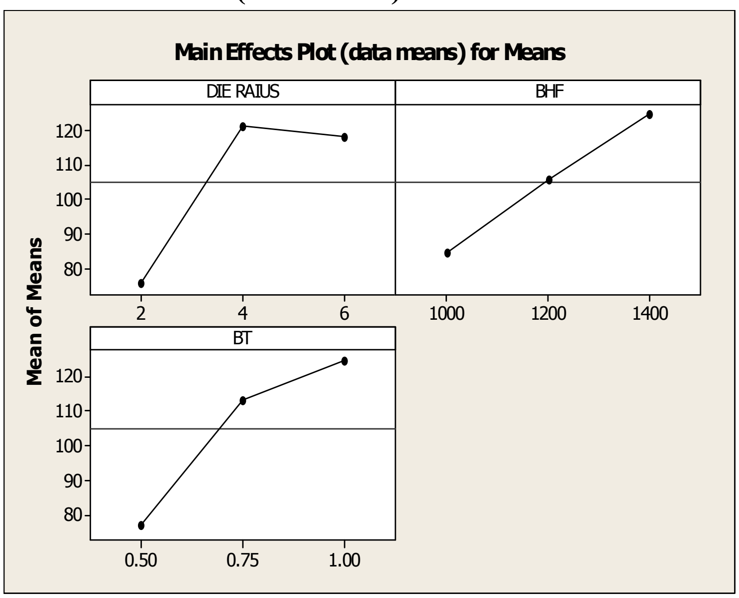
Response Table for Signal to Noise Ratios
Smaller is better

Level	DIE RAIUS	BHF	BT
1	-29.98	-29.28	-29.68
2	-27.65	-28.01	-28.60
3	-27.75	-28.09	-27.10
Delta	2.33	1.26	2.58
Rank	2	3	1

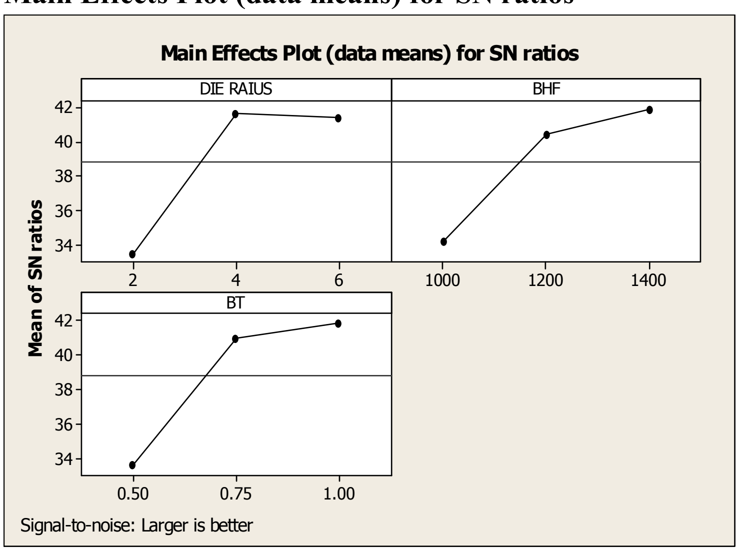
Response Table for Means

Level	DIE RAIUS	BHF	BT
1	32.89	30.57	31.78
2	24.26	25.52	27.16
3	24.46	25.51	22.67
Delta	8.63	5.06	9.11
Rank	2	3	1

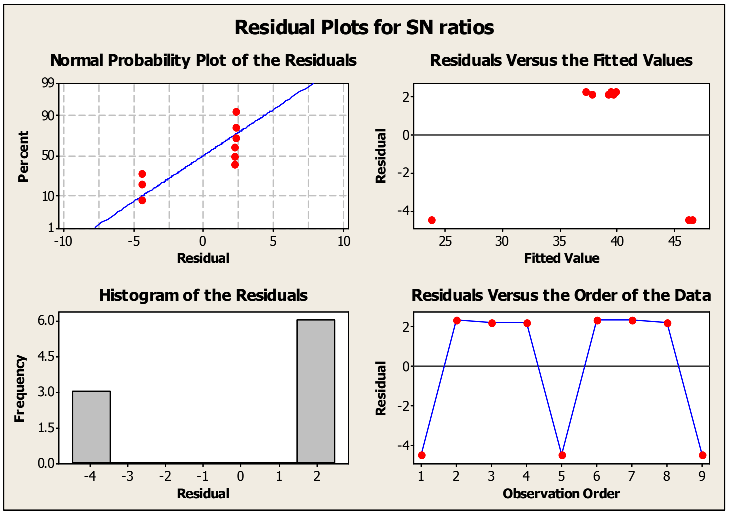
Main Effects Plot (data means) for Means



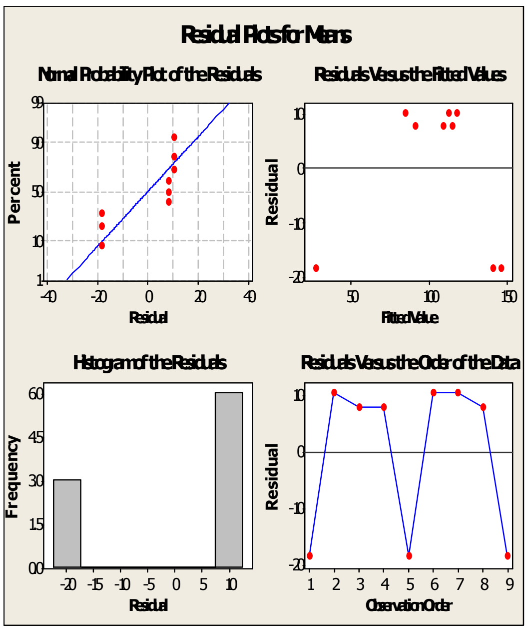
Main Effects Plot (data means) for SN ratios



Residual Plots for SN ratios



Residual Plots for Means



it is found that maximum thinning % on BHF 1200 N, with Die entry radius 2 and minimum on BHF1200 N Die, with entry radius 4 at blank thickness 1 mm & minimum thinning % on BHF 1000 N, with Die entry radius 2 and maximum on BHF1400 N, with Die entry radius 6 at blank thickness 1 mm.

Conclusion:

- The operating values for different process variables for multi-parametric response optimization with equal weightages are obtained as:
    - Die Radius : 4 mm
    - BHF :1400 N
    - Blank thickness : 1 mm
- While considering varying importance (weightages) of different performance parameters. It indicates that the operating parameters can be set appropriately so as to satisfy.
- Based on S/N ratio, it is found that the influence of Die radius is

higher *i.e.* around 47%, followed by BHF 16.93% and Blank thickness as 16.45% on quality characteristic of the circular cup. It indicates that o Die radius has major influence on the deep-drawing process, followed by blank holder force and blank thickness.

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