Taguchi Optimization Approach for Investigation of Draw Dies Parameters for Reduction of Material Thinning using FEA.

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ABSTRACT

Sheet metal forming processes are widely used in automobile industries. One of the most sensitive features of the sheet metal deep drawing is material flow recovery during unloading called spring back. Accurate prediction and controlling of material flow is essential in the design of tools for sheet metal forming. The Deep draw material flow is affected by the factors such as sheet thickness, material properties, tooling geometry, blank holding force, Bead geometry, Punch travelling speed etc. The quality of sheet metal part is controlled by the material flow into the die cavity. Draw beads are often used in sheet metal forming to restrain the sheet from flowing freely into die cavity. There are several parameters that affect material flow such as punch angle, die opening, ratio of die, radius to sheet thickness, sheet thickness punch radius, punch height, Blank holding force, bead size location, bead size, pre bend condition of strip etc. Through optimization method can be used to find out the best combination of most influencing parameters with FEA Auto stamp simulation software and from optimized taguchi parameters for better material flow , experimentation trial can be confirmed Taguchi optimization is one of the best technique to find out the best optimum solution , there can be from full factorial design of experiment or fractional factorial design of experiment method depending on trial cost and time required. As per current situation in automotive companies, especially for stamping manufacturing it is very necessary to find out the optimum solution at product and process design phase.

Keywords: ***Deep draw Auto stamp, Taguchi optimization, Blank holding force, Bead***.

1. INTRODUCTION

In sheet metal forming, the rate of material flow into die cavity must be controlled so that a better quality is maintained and defects like wrinkling, tearing and galling are prevented. Generally the restraining force required to control the material flow is provided by either the blank holder or the Drawbeads. The blank holder creates restraining force by friction between sheet and the tooling. When a high restraining force is required, higher binder pressure must be applied to increase the frictional resistance force, which may cause excessive wear in the tooling and galling in strip. The draw bead consists of a small groove on the die surface / binder surface matched by protrusion on the binder surface / die surface as shown in Fig 1. After the binder closure, the sheet metal is drawn over the draw bead and is subjected to a bending and a subsequent unbending around the entry groove shoulder, bead and at the exit groove shoulder. These bending and unbending deformations together with the frictional force account for the draw bead restraining force.

1.1 Draw forming process

Draw forming is process to produce cups, shells, boxes and similar parts from metal blank. It is a sheet metal forming process in which a sheet metal blank is radially drawn into forming die by the mechanical movement of the punch. It is thus a shape transformation process with material retention. A simple drawing operation is shown in fig 1. A round blank is first cut from flat stock. The blank is then placed in the draw die, where the punch pushes the blank through the die. On the return stock the cup is stick with punch, to avoid this blank holder is used. Generally, a drawing operation is referred to as shallow drawing when the depth of cup is less than the diameter of cup and drawing of cup is deeper than half its diameter then it is called deep drawing

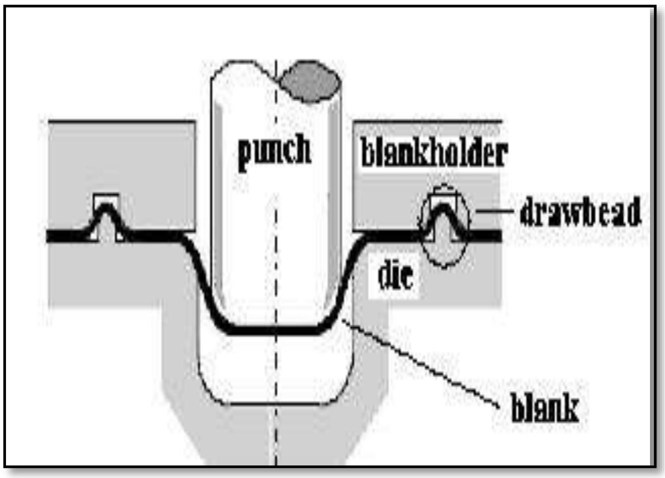

Fig-1: Forming Die parameters

2. MODELING FOR MATERIAL THINNIG

Material flow is affected by various factors punch nose radius (Rp), die profile radius (Rd) and blank holder force (BHF), Coefficient of friction , Material thickness , Draw bead geometry etc. Material flow ,Material thinning is one of the major cause of concern in sheet metal forming industries which leads to product failure in the deep drawing operation and further it affect quality loss of product and value loss in process. The problem has been taken in the paper is to study the material flow distribution phenomenon due to Blank holding force, Draw bead, material thickness using this parameters and validate the results using DOE and analysis of variance.

2.1 Material Selected

Material Grade - CRCA steel DD grade as per JIS G3141/IS513 (M21 DD)

Standard preferred for raw material Mechanical and chemical Properties selection: Grade designation for low Carbon cold rolled steel sheets used for automotive applications.

Standard no: G00 0167, Revision: C, Reference: SRN00281, Date: 30.10.2007

Mechanical Properties –	**Chemical Properties**
TS – 270 to 370 N/mm2	C% - 0.10max
Y.S–250N/mm2	Mn% - 0.45max
Elongation- 32% Min	S% - 0.035max
Hardness – 50 HRB	P% - 0.035 max
Rbar–1.6mic micron	

Table-1: Material properties

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2.2 Geometric and process Parameters

Blank Size	300mmX200mm
Blank thickness	1.0
Punch Radius	2.4mm
Die Radius	4.0mm
Surface roughness	3.2 micron
Drawing speed	0.28m/sec
Blank Holding force	15
Bead Depth	6
Punch travel	30mm

Table-2: Geometric and process Parameters

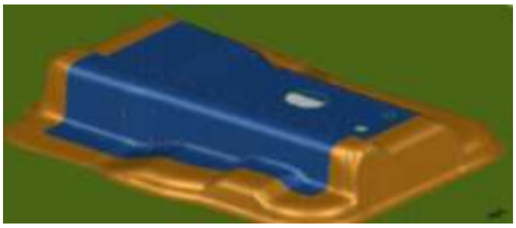

Figure-2: Die geometry

3. TAGUCHI DESIGN

In this paper the prediction of the material thinning in deep drawing process using FEA simulation process and DOE/Taguchi approach to study the effects of process parameters such as between BHF,Draw Bead and Material thickness, these three factors were the most significant factors which directly affects the amount of material flow in final product and hence in the present investigation these three factors are consider. In this case it is necessary to have thinning value in deep drawn must be less as possible, i.e., the smaller values are preferred for the component. Taguchi design it is also called as an orthogonal array is a design of experiments method of that requires only a fraction of combinations of full factorial. An orthogonal array balanced the design such a way that factor levels are equally weighted. Due to this, each and every factor can be evaluated separately of all the other factors; due to this the effect of one factor does not affect the estimation of another factor. Under Taguchi method having 3 parameter with 3 levels can be performed with 09 experiments. Therefore in Forming FE simulation, 09 experiments are selected to analyze each characteristic of each experiment effectively.

Factor	Unit	Level 1	Level 2	Level 3
B.H.F	Ton	12	15	18
Bead Depth	Mm	0	3	6
Blank Thickness	Mm	0.8	0.9	1.0

Table-3: Process Parameters & Level

Exp. No.	Parameters		
	BHF	**Bead Depth**	**Thickness**
1	12	0	0.8
2	12	3	0.9
3	12	6	1.0
4	15	0	0.9
5	15	3	1.0
6	15	6	0.8
7	18	0	1.0
8	18	3	0.8
9	18	6	0.9

Table-4: Orthogonal Array (L9) Of Taguchi Method

Taguchi approach is most powerful Design of experiments (DOE) tool for optimization of engineering process in the tool the concept of Signal to Noise ratio (S/N ratio) is used for improvement of quality through variability reduction and improvement of measurement. There are many types of Signal to Noise ratios (S/N ratio) available for study as follows.

Larger is better: It is choosing when the goal is to maximize the response.

Nominal is best: It is choosing when the goal is to target the response and you want to base the S/N ratio on standard deviations only.

Nominal is best: It is choosing when the goal is to target the response and want to base the S/N ratio on means and standard deviations (default).

Smaller is better: It is choosing when the goal is to minimize the response.

In essence the spring back in deep drawn cup must be smaller, so for this work Smaller is better S/N ratio type were selected. S/N ratio had determine for each and every experiments and the experiments are carried out using FEA and the values of spring back obtained from each experiments is listed in table 5

4. ANOVA

The use of the ANOVA is to investigate which process parameters considerably affect the quality characteristic. It is a statistical approach evaluated for percentage of contributions (%) for variance by each input factor. In ANOVA collection of statistical models is done and related procedures used to get the contributions of each parameter on the output characteristic. In this paper ANOVA is used to clarify the input parameters, i.e. *BHF*, *Bead* and Thickness that noticeably influence the spring back. The information on weightage of each parameter on thickness distribution was get furnishes. It is recommended by Taguchi that, a logarithmic transformation of mean square deviation (S/N ratio) for the analysis of results. ANOVA approach separates the overall variation from the average Signal to noise ratio (S/N ratio) into contribution by each of the parameters and the errors.

5. RESULT AND DISCUSSION

In this study, the material thinning percentage in deep drawing process was explored by investigating the effects of different process parameters, such as BHF, Bead and Thickness. A model was developed by Auto stamp software package for prediction of thinning % in the material CRCA DD steel in deep drawing process related to spring back phenomenon. The Auto stamp solver is used as the solver which gives the results. The reading of material thinning obtained was converted into signal to noise ratio.

The springback percentage was calculated from formula

% thinning = [{Original thickness} – {changed thickness} / Original thickness] *100.

This thinning percentage was calculated for each of nine experiments as shown in table no.

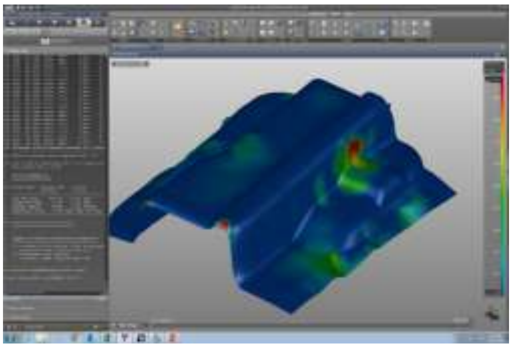

Figure-3: Simulated panel for thinning %

Exp No.	% of Spring back (FEA)
1	11.8758
2	10.1600
3	10.1350
4	9.6380
5	10.9200
6	12.4665
7	13.7200
8	15.4575
9	16.7110

Table-5: FEA simulation results as per Taguchi L9 Exp array

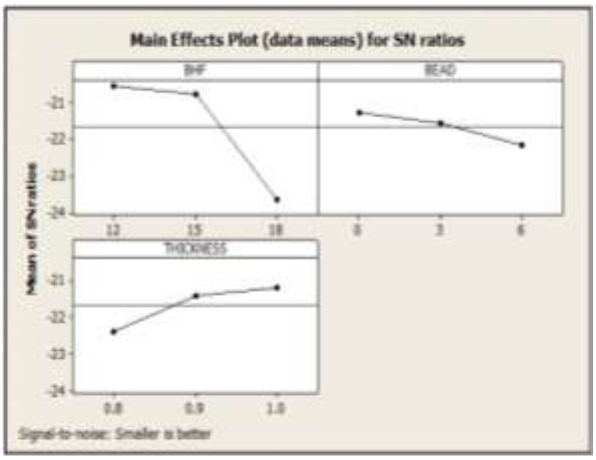

Figure-4: Main effect plot for S/N ratio.

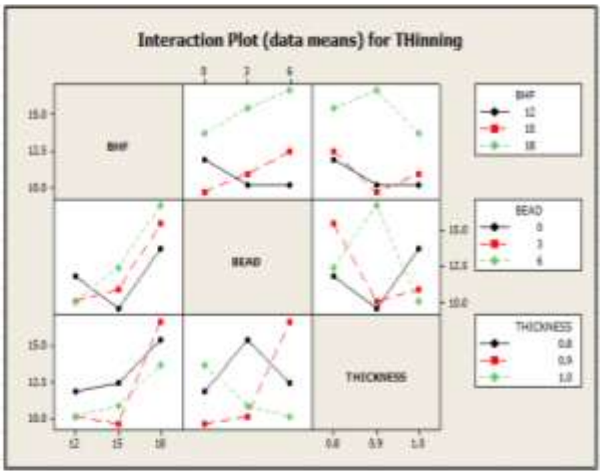

Figure-5: Interaction plot for Thinning

Levels	A	B	C
1	-20.58	-21.31	-22.40
2	-20.79	-21.56	-21.43
3	-23.66	-22.16	-21.21
Delta	3.08	0.86	1.19
Rank	1	1	3

Table-6: Response Table for Signal to Noise Ratios

Process Parameters	Level Description	Level
BHF	12	1
Bead Depth	0	1
Thickness	1.0	3

Table-7: Optimum Condition

As the optimum combination level is not in the one of the experimental runs (according to Table 4) an extra confirmation run is required. That extra run was done again by FEA simulation and found that the % of material thinning percentage as 9.235 % and this value was compared with predicted Taguchi smaller is better S/N ratio value which is --20.1641with % of material thinning given by Taguchi and FEA analysis are about to same with having negligible error.
Finally the importance of the process parameters was estimated by the ANOVA statistical approach. The results of ANOVA are calculated using Minitab and shown in a table 8. And main effect plot of s/n ratio shown in Figure 3. The blank holder force (BHF) has most significant process parameter followed by material thickness (t) and bead depth small significant parameter is influencing material thinning.

Source	DF	S	MS	F	% Contribution
BHF	2	17.809	8.9047	10.67	48.0805
Bead Geometry	2	11.162	5.5811	8.70	30.1350
Thickness	2	6.400	3.2002	4.44	17.2786
Error	2	1.669	0.8345	…	
Total	8	37.04			95.45
S = 0.9135 R-Sq = 95.45% R-Sq(adj) = 94.3%					
All F-ratios are based on the residual mean square error.					

Table-8: ANOVA Results

6. CONCLUSION

Several conclusions can be obtained from the results of the study:

1. The finite element simulation provides a satisfactory prediction of material thinning percentage results with Taguchi approach.

2. The results from this work open the platform of determination of optimum blank holder force, Material thickness, Bead Geometry for enhance quality products.

3. Anova results reveal that blank holding force has most significant parameter 48.08%, followed by bead depth 30.13% and the material thickness17.28% has lower effect on % of material thinning

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