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Optimization of Process Parameters in Deep Drawing Operation

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ABSTRACT

Wrinkling and tearing are common surface defects in sheet metal forming. It is unacceptable in the head light reflectors, because, any alteration in the reflector contour may affect its functionality. Due to the rejection or rework of the defective part, there is wastage in the production process, not only in terms of time but money as well. So, the prediction and prevention of defects becomes necessary. ***Luman Auto Light Pvt. Limited*** *was facing a problem in manufacturing of the headlight reflector. The problem was that wrinkles appear on the curved surface of reflector along with cracking in some of the parts during the drawing operation. Therefore, it was necessary to find out the causes of wrinkling and cracks so as to minimize losses.*

In experimental methodology, three basic steps were carried out to find out the causes of defect in the drawn component.In the first step, the process was studied to explore the various causes for the wrinkle formation. The process was studied in detail and the actual conditions in the company were also studied. In the second step, Taguchi method was used to design the set of experiments that were to be carried out for the defect analysis of the drawn component. Three parameters were varied at four levels each and L16 orthogonal array was used. Three parameters were blankholder force, friction coefficient and punch speed. In the third step, simulation of the experiments gave results in the form of thickness distribution. Using signal to noise ratio, the optimum level of each parameter was decided. Further, the contribution of eachParameter to the quality of the drawn component was studied.

Keywords- Wrinkling, Tearing, Head light reflector, Taguchi Method, L16 orthogonal array, Signal to noise ratio.

I INTRODUCTION

Deep drawing operation depends upon many parameters like blankholder force, friction conditions, material properties of the blank, die radius, punch radius, punch-die clearance, punch speed and sheet thickness. In the present work three dominant parameters that are blankholder force, friction coefficient and punch speed were varied to find out the reasons that caused wrinkling and thinning.

II PROBLEM DEFINITION

Luman Automotive Systems Pvt. Ltd. situated at Udyog Nagar New Delhi is a leading manufacturer of various sheet metal components. The Head Light reflector manufactured by company for Tata 407 vehicle is made by deep drawing operation is having wrinkling and cracking defect.

The part is having the problems of wrinkling and tearing during the drawing operation as shown in Figure2.1.

(a) (b)

FIGURE 2.1 Defected Part having (a) Wrinkling and (b) Tearing

These defected parts cannot be assembled in headlight as it will affect the functionality of headlight reflector.

III EXPERIMENTAL METHODOLOGY

The various parameters that affect the drawing operation like Blankholder force, friction coefficient and punch speed were studied. It was observed that smaller value of blankholder force was responsible for wrinkle formation while the larger value resulted in tearing of sheet. Larger value of friction helps obtaining good drawable height. Smaller value of punch speed helps in drawing of the component by restraining the material flow while larger value could results in to tearing of sheet.

The work piece was a sheet of size 325 mm x 300 mm x 0.75 mm. The material of sheet was IS: 513 DD grade (Deep Draw) Cold Rolled Close Annealed (CRCA) steel.

3.1 Design of Experiments

In this work, it was planned to study the behaviour of three control factors which were, A (Blankholder force), B (Friction coefficient) and C (Punch Speed). The observations from simulation results were further transformed into signal to noise (S/N) ratio. There are several ratios depending upon objective of optimization of the response. The characteristic with higher value represents better quality drawing **[33].**

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TABLE 3.1 LEVELS OF CONTROL FACTORS

DESIGN FACTORS ↓	LEVELS			
	1	**2**	**3**	**4**
A (Blankholder force) (kN)	75	100	125	150
B (Friction Coefficient)	0.01	0.057	0.104	0.15
C (Punch Speed) (mm/s)	100	150	200	250

3.1.2 Simulation

The experiments decided by Taguchi approach were simulated in Simufact 11.0.1 application software. A total of 16 experiments were carried out as decided by L16 orthogonal array.

IV RESULTS AND DISCUSSIONS

4.1 Signal-to-Noise Ratio and Response of Process

One of the quality criteria in sheet metal formed parts is thickness distribution. Failure in deep drawn components generally takes place by thinning; hence, it is desirable to determine the variation of strain in thickness direction during deformation. The objective is to reduce thickness variation in deep drawn part as well as minimize thinning. Therefore, in this study, the response selected from the experiments is thickness distribution. Taguchi's main idea was to control the noise factors indirectly by examining how they are affected by different settings of control factors. It analyses the combined effects of control and noise factors, and for this purpose, proposed performance criteria known as signal-to-noise ratio (S/N). **[19]:**

$$S/N = 10\log(y^2_m / s^2) \qquad \text{…(4.1)}$$

$$s^2 = \Sigma(y_i - y_m)^2/(n-1) \qquad \text{…(4.2)}$$

$$y_m = \Sigma\, y_i / n \qquad \text{…(4.3)}$$

Where y is the measured value of thickness, and n is the number of positions for measured values of y.

The S/N ratios were calculated along the profile on the component as shown in Figure 4.1.

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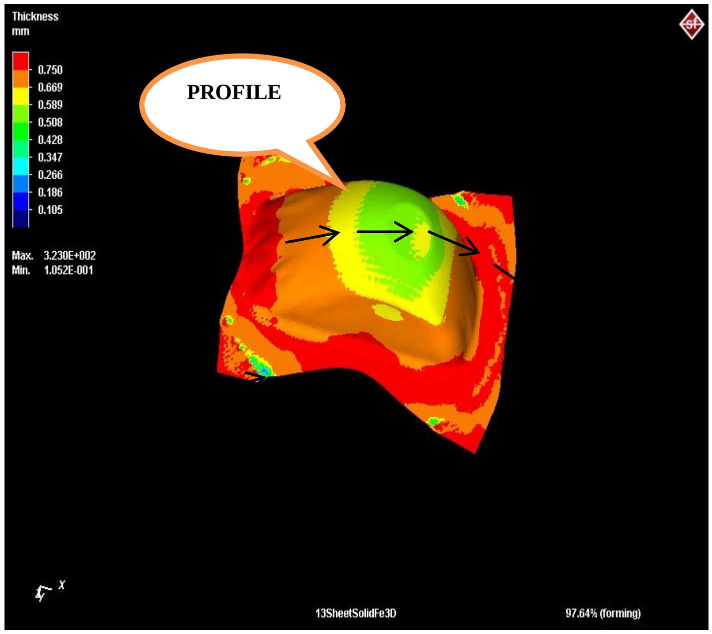

FIGURE 4.1 THICKNESS VALUES TAKEN ON COMPONENT

The S/N Ratio that were calculated from equations 4.1 to 4.3 are given in Table 4.1

TABLE 4.1 S/N RATIOS FOR EXPERIMENTS

EXPERIMENT NO.	S/N RATIO	EXPERIMENT NO.	S/N RATIO
1	17.377694	9	17.405692
2	17.942578	10	17.750066
3	17.956835	11	17.434178
4	15.198881	12	16.229857
5	17.30045	13	17.679104
6	17.609999	14	18.216518
7	17.200994	15	17.767581
8	15.657024	16	16.632930

The level average and the percent contribution of each parameter were calculated as described below **[19].** The overall mean from which all the variation is calculated is given by

$S/N_m = (1/n)\ \Sigma\ (S/N_i)$ ------ (4.4)

Where n is the number of test runs.

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The grand total sum of squares (GTSS) is given by

$S_T = \Sigma (S/N_i)^2$---------(4.5)

It can be decomposed in to two parts: the sum of squares due to overall mean and the sum of squares due to variation around overall mean:

$S_T = S_m+S_v$ ------ (4.6)

The sum of squares due to overall mean is

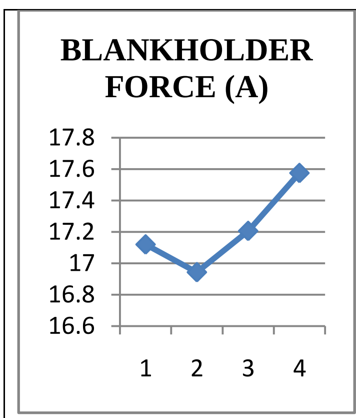
$S_m = n.(S/N_m)^2$ ------- (4.7)

Where n is the number of test runs. The sum of squares due to variation around overall mean is

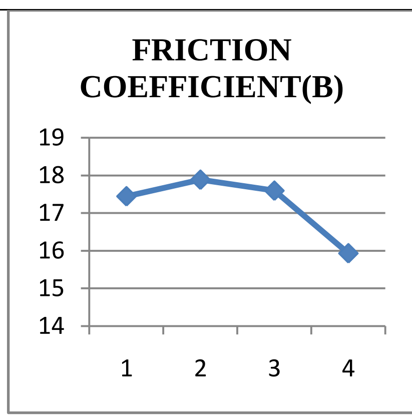
$S_v = (1/n)\ \Sigma(S/N_i-S/N_m)^2$ ------ (4.8)

The S_v can be further decomposed in to the sums of the squares of the variation induced by individual parameter effects around overall mean. For parameter A, the sum of squares due to variation around overall mean is;

$S_{jA} = n_{A1}(S/N_{mA1}-S/N_m)^2 + n_{A2}(S/N_{mA2}-S/N_m)^2 +n_{A3}(S/N_{mA3}-S/N_m)^2$--- ----- (4.9)



(a)



(b)

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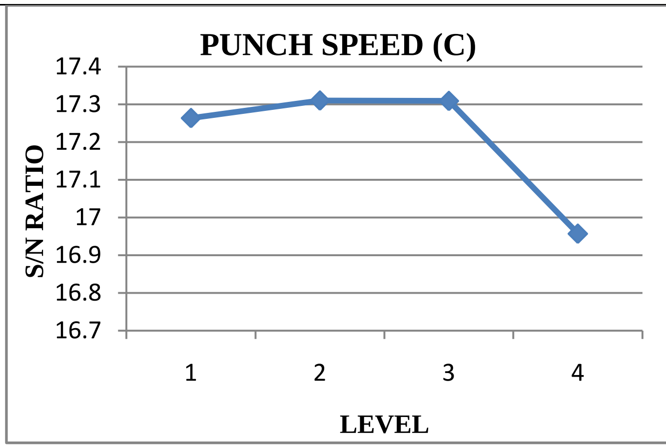

(c)

FIGURE 4.2 PLOTS OF LEVEL AVERAGE VALUES OF THREE PARAMETERS (A) BLANKHOLDER FORCE; (B) FRICTION COEFFICIENT; (C) PUNCH SPEED

Where n_{Ai} is the number of tests conducted at level i of parameter A; S/N_{mAi} is the level average S/N of parameter A at level i.Similarly, the sum of squares due to variation around overall mean is calculated for the remaining two parameters. Then, the contribution of each parameter is calculated:

$C_j = S_{jA}/S_v$ ----- (4.10)

The mean value of S/N ratio in all experiments is given as 17.210023. The level average response analysis by S/N ratios is shown in Figure 4.2.

For optimum values of the selected parameters, the level that gives the highest S/N ratio was chosen **[19].** Therefore it can be concluded that optimum level for BHF, Friction Coefficient and Punch Speed is 150 kN, 0.057 and 150 mm/s respectively.

Equations 4.8, 4.9 and 4.10 are used to find the values of S_v, S_j and C_j. The value of S_v is 10.33837. The calculations of contributions of the parameters are shown in Table 4.3.

TABLE 4.3 CONTRIBUTIONS OF PARAMETERS

PARAMETER	LEVEL	S/N_{mn}	S_j	% CONTRIBUTION
A (BHF)	75 kN	17.118997	0.850356	8.22524
	100 kN	16.942116		
	125 kN	17.204948		
	150 kN	17.574033		
B (FRICTION COEFFICIENT)	0.01	17.440734	9.141664	88.424616
	0.057	17.879790		
	0.104	17.589897		
	0.15	15.929673		
C (PUNCH SPEED)	100 mm/s	17.263700	0.346352	3.350160
	150 mm/s	17.310116		
	200 mm/s	17.309017		
	250 mm/s	16.957261		

It can be observed that the maximum contribution is of Friction coefficient i.e. 88.4%, followed by Blankholder force and Punch Speed.

The Friction Coefficient has maximum effect on quality of drawn component with the percentage of 89%. This is followed by Blankholder force with percentage of 8%. The Punch Speed has lowest contribution with a percentage of 3%.

4.2 Simulation of the Drawing Operation Using Optimized Parameters

The simulation was performed using optimum parameters as defined by Table 4.4. The thickness distribution in simulation as per optimum parameters and existing parameters is shown in Figure 4.3.

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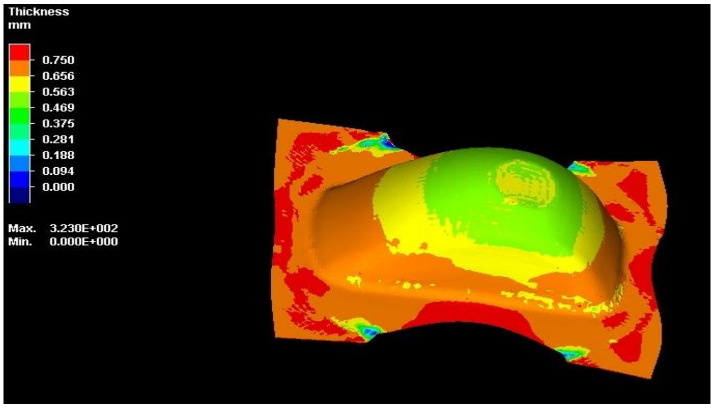
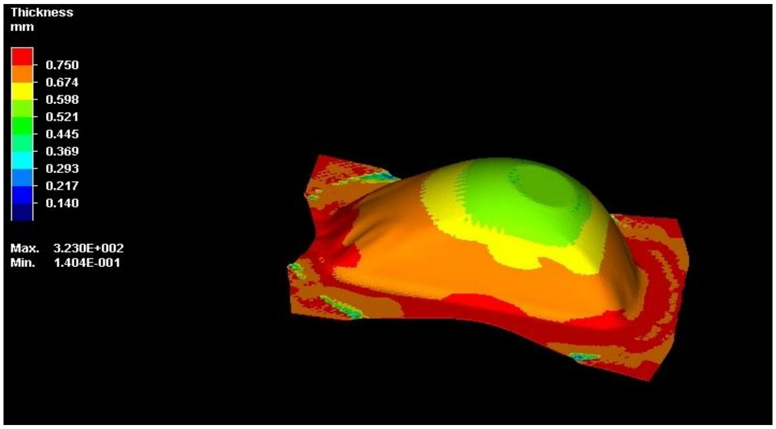


(a)



(b)

FIGURE 4.3 THICKNESS DISTRIBUTION OBTAINED WITH(a) OPTIMISED PARAMETERS AND (b) EXISTING PARAMETERS

On comparison with actual case it was found that the wrinkled region at curved inclined portion had reduced. It was also observed that, in the wrinkle prone region, the variation in thickness with optimized parameters was 0.65 mm to 0.75 mm, whereas, it was 0.65 mm to 0.85 mm, in case of existing parameters. This indicates an improvement in thickness distribution. So, it was concluded that the wrinkles could be reduced by using optimized parameters. Though, the thinning area around the nose radius increased, but still, the minimum thickness was 0.469 mm, which was more than the actual case where the minimum thickness was 0.293 mm.

V .CONCLUSIONS

Various conclusions were derived from the analysis of the results which are discussed below;

(i) It was observed that the most dominant parameters that affected the drawing operation were blankholder force, friction coefficient and punch speed.

(ii) The friction coefficient contributed 80 % to the quality of drawing operation. The optimized value was 0.057, while, the actual value that was being used was 0.01. So, the larger of friction coefficient could be used so that the material flow can be constrained, because more metal flow into the die cavity results in thickening of sheet and hence, wrinkling.

(iii) The blankholder force had a contribution of 15%. The actual value was 100 kN, while, the recommended value is 150 kN. This implies that the blankholder value must be increased for the proper metal flow while drawing.

(iv) The punch speed had a contribution of 5%. The actual value was 200 mm/s and it is to be reduced to 150 mm/s to improve metal deformation rate.

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