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Experimental Analysis and Optimization of Clearance between Punch and Die in Sheet Metal Blanking Process for Soft Steel

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Abstract

Blanking process is commonly used process in production of sheet metal industries to fabricate components. The Global market of sheet metal production is facing highly competition. Due to unavailability of skilled operators and shortage of affordable CAD/CAM systems, it is difficult to predict optimum clearance between punch and die to obtain high quality in small scale industries. Blanking is metal fabricating process and it is characterized by complete material separation. The simulation of the shearing process is complicated as the shear band formed is narrow and fracture criterion is inappropriate. The effect of potential parameters like thickness of sheet, punch-die clearance, tool wear, and punch geometry are studied to investigate their interactions on blanking process. It is important to select process leading parameters which can lead the process such that two similar products from two separate materials can be manufactured on same mold with high quality. This study will help to investigate the effect of thickness of sheet, clearance between punch and die and type of material on blanking process and will help to predict optimal set of parameters to obtain reasonable quality. A mathematical model of blanking process is developed and design of experiments method is used to predict optimum punch-die clearance for soft steel which will result into high quality of component.

Keywords: Experimental Analysis, Material Separation, Optimization, Sheet Metal, Soft Steel

1.0 Introduction

Blanking is frequently used in fabrication of metal sheets in mechanical industry. In this operation a part of sheet metal is removed with the help of punch and die set up. The part of the material which is removed is mentioned as Product. In blanking process, a metal punch is forced on the larger sheet of metal where die is already set on hydraulic press. High accuracy and high-quality products with good finishing are demanded by market where such parts are used for different applications.

This paper presents a method of prediction of optimum punch-die clearance by using design of experiment method with the help of Taguchi method. Aluminum, brass, soft steel, bronze and mild steel are frequently used materials in blanking process. This study is related with soft steel which is very economical material used in the blanking processes.

A sheet of required material is pushed by using a blank holder and then punched by using a punch tool. The modelling of blanking technique is complicated because it is difficult to describe that process starts with elastic stage and finally product gets separated from

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sheet and process ends. Four characteristic dimensions i.e., depth of roll over zone, depth of shear zone, depth of fracture zone and height of burr formed can be observed on the blanked product. Figure 1 shows the schematic representation of the blanking process with different zones.

2.0 Fundamentals of the Sheared Part

The properties of different materials, shape of tool, wear of tool and noise factors can affect the quality of product in blanking[4,5]. Figure 2 shows the Geometry of the sheared work piece.

- Depth of Rollover: Due to plastic deformation of material
- Depth of shear: shiny and smooth surface duet to shearing
- Depth of fracture/Rupture: Surface becomes rough due to cracks
- Burr height: Results of plastic deformation
- Depth of crack penetration: Clearance affects the angle of fracture[2]

3.0 Complications in Blanking Process

- Design of Blanking process: In industry, as the knowledge about optimum value of clearance is limited so operations are performed using trial and error experimentations. This issue makes the blanking process time consuming and expensive.
- Lead cycle time is increased due to trial-and-error method which also causes poor quality products[7].
- Quantity of rejection is more for manual inspection.

4.0 Factors/Errors Influencing Blanking Process

Accuracy of product can be affected by positional error, dimensional error and form error as shown in Figure 3. Figure 4 shows the punch and die clearance.

Type of material, the shape of tool, process variations and the machine can create errors in blanking process.

Therefore, clearance between punch die and tool geometry are the most significant parameters.

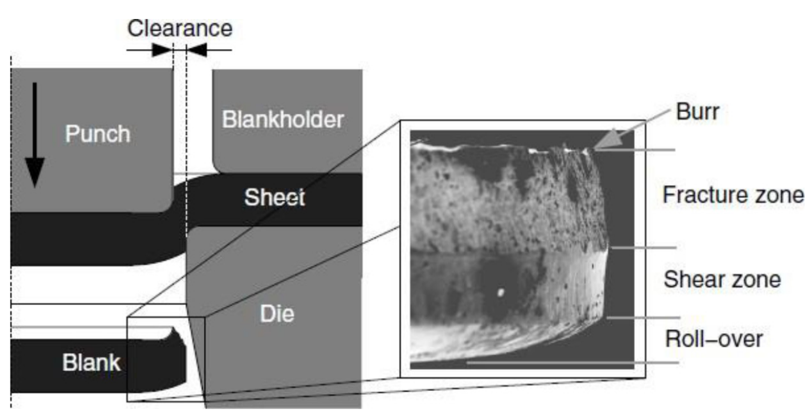

Figure 1. A schematic representation of the blanking process with different zones[1-3].

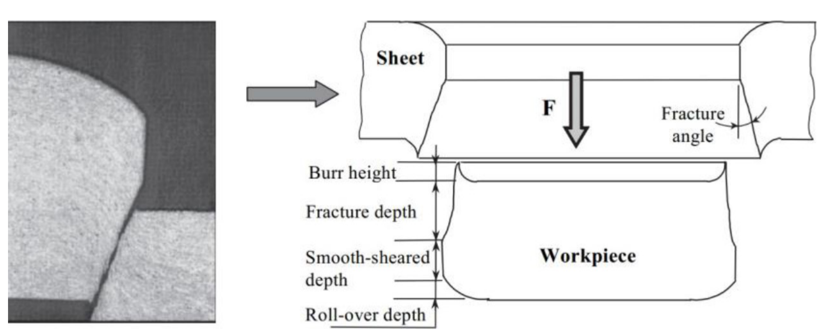

Figure 2. Geometry of the sheared work piece[5,6].

5.0 Design of Experiment by Taguchi Method

In Taguchi experimental design method, number of experiments are set with the help of Orthogonal Array (OA). In this way, different parameter's effect can be checked on the performance characteristics. In this approach, first we need to finalize the parameters which are affecting the process[8,9]. After this we will decide the levels in which each parameter is needed to vary. OA will give the number of experimental sets based upon the number of parameters and their levels. In this study, 2 parameters are selected i.e., thickness and clearance. For each parameter 3 levels are selected and so from orthogonal array selector, L9 OA is selected for 2 parameters and 3 levels as shown in Table 1.

6.0 Analysis of Soft Steel

Table 2 shows the Response Table for signal to noise ratio and mean for soft steel.

6.1 Signal to Noise Ratio Analysis and Means of Burr Height

- Quality Characteristic: Burr Height of Blanked Component
- Quality Characteristic Feature: Smaller-the-better. Table 3 shows the Signal to Noise Ratio and Mean of Burr height
- The effect of variable is more on the process when the value of the delta is higher.
- According to SNRA and Mean Analysis, Delta for clearance is larger than delta of thickness. It concludes that clearance is the major affecting parameter in blanking process.

Figure 5 shows mean value of burr height as a horizontal line. Basically, smaller the means, i.e., burr height, the better is the quality of product for the blank. To get optimum value of burr height, settings required are A_3B_1

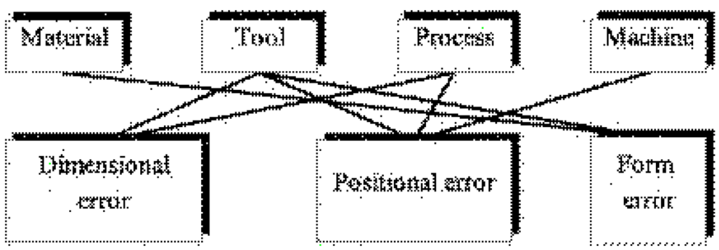

Figure 3. Factors affecting errors on blanked work pieces.

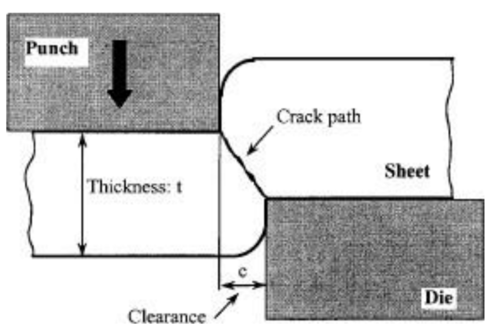

Figure 4. Illustration of the punch and die clearance.

Table 1. Taguchi design of L9 OA

Ex. No.	1	2	3	4	5	6	7	8	9
Thickness(mm)	0.5	0.5	0.5	0.8	0.8	0.8	1.5	1.5	1.5
Clearance (%)	5	10	15	5	10	15	5	10	15

Hydraulic Power Press of 10 tonne capacity is used for experimentation.
Vernier Height Gauge is also used for calculation of burr height (Least Count 0.001mm)

6.2 Analysis by ANOVA

From Table 4, it can be concluded that clearance is the more affecting parameter to the burr height. It can be concluded that when the small variation happens in the parameter which is contributing with higher percentage, then it can affect the performance greatly. According to ANOVA analysis, major parameter affecting the burr height is clearance (14%). Sheet thickness contribution

Table 2. Response table for signal to noise ratio and mean for soft steel

Experi ment no.	Thickness (mm)	Clearance (%)	Sample 1	Sample2	Sample3	Sample4	Sample5	SNRA	MEAN
1	0.5	5	0.0881	0.0891	0.0898	0.08926	0.08286	21.1241	0.087824
2	0.5	10	0.09121	0.09314	0.09413	0.1012	0.1905	18.3931	0.114036
3	0.5	15	0.2032	0.2159	0.2034	0.2036	0.254	13.2745	0.216020
4	0.8	5	0.05352	0.05212	0.05326	0.05426	0.06301	25.1337	0.055234
5	0.8	10	0.08232	0.08329	0.08321	0.08213	0.0921	21.4429	0.084610
6	0.8	15	0.1016	0.1143	0.127	0.1397	0.1524	17.8379	0.127000
7	1.5	5	0.0381	0.0254	0.0381	0.0254	0.0508	28.6811	0.035560
8	1.5	10	0.0508	0.0504	0.05	0.0506	0.0502	25.9513	0.050400
9	1.5	15	0.1397	0.1651	0.1143	0.1016	0.1524	17.2868	0.134620

Table 3. Response table for signal to noise ratio and mean of Burr height

Level	SNRA analysis		Mean analysis of Burr	
	A (Thickness)	B (Clearance)	A (Thickness)	B (Clearance)
1	17.60	24.98	0.13929	0.05954
2	21.47	21.93	0.08895	0.08302
3	23.97	16.13	0.07353	0.15921
Delta	6.38	8.85	0.06577	0.09967
Rank, R	2	1	2	1

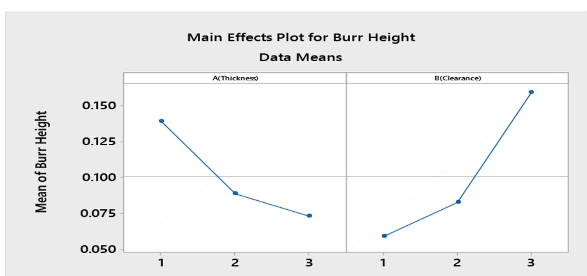

Figure 5. Main effect plot for mean of Burr height.

Table 4. ANOVA for SNRA

Source	DF	Seq SS	Adj SS	Adj MS	F	Percent Contribution
Thickness	2	60.151	60.151	30.075	14.82	0.004
Clearance	2	122.154	122.154	61.077	29.6	0.14
Error	4	8.253	8.253	2.063		
Total	8	191.558				

Table 5. Regression analysis: MEAN versus thickness, clearance

Predictor	Coef	SE Coef	T-value	P-value	VIF
Constant	0.06668	0.02773	2.40	0.053	
Thickness	-0.032883	0.009419	-3.49	0.013	1
Clearance	0.049837	0.009419	5.29	0.002	1

The Regression equation is

BURR HEIGHT = 0.0667 - 0.03288 A (Thickness) + 0.04984 B (Clearance) S = 0.0230709, R-Sq =87.0%, R-Sq(adj)=82.7%, R-sq(pred)=66.67%

Solving previous regression equation by MS EXCEL-SOLVER

Table 6. MS EXCEL SOLVER optimum values

X Thickness	Y Clearance	Z Burr height
0.07353	**0.05954**	**0.067246**
0.08895	0.08302	0.067908
0.13929	0.15921	0.070046

is much lower, i.e. only 0.4 %. There is no need of confirmation experiment as optimum level condition A3B1 has been already performed.

6.3 Regression Analysis

Table 5 shows the Regression Analysis: MEAN versus thickness, Clearance

Table 6 Shows that the lowest Burr height value is 0.067246 mm related to 0.05954 clearance, i.e., 5.954%. So minimum burr height obtained for clearance which is 5.954%.

7.0 Conclusion

This study shows that, for zero blank holder force, about 5% clearance value is required to optimize the quality of the product. The optimum process parameters are predicted by using design of experiment method. Lead-time can be reduced by using Taguchi Method, where computer software like Minitab, Design expert can substitute many slow trial and error experiments. Due to this, the process becomes more reliable and less time-consuming.

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