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Modification of Tooling Striper Plate Machine Cross Pieces Cut to Extend Die Plate Life

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A B S T R A C T

Part stamping is the result of a production process known as sheet metal forming, which is essential for producing pressed sheet metal components. This process requires sheet metal plates, pressing dies as molds, and pressing machines. The objective of this study is to extend the service life of the striper plate and die plate by modifying the tooling in the cross-cutting section of the engine block using Response Surface Methodology (RSM) for data analysis, in order to optimize the punch length and air pressure parameters. The modification was applied to the tooling plate (striper) of the cross-cutting machine block, allowing previously discarded die plates to be reused in the production process. Data observation and processing were conducted using Minitab 16. The results showed that the mass usage of the die plate was not significantly affected by the three variation parameters used in the study. The modification process involved adjusting the right side of the lower striper tooling plate, giving it a width of 26 mm and a gradual depth ranging from 0.5 mm to 1.5 mm. After modification, the tooling was reassembled and applied in the next production cycle. Observational data were collected and analyzed using Minitab 16 to determine the optimum values through response surface analysis.

1. INTRODUCTION

The cross pieces cut and U-bend machine is a production machine used to cut a pair of terminal hooks on the coil terminal and split the terminal into two parts: upper and lower. Subsequently, the material is bent (bending) to proceed to the next process. Damage occurring during the cross pieces cut and U-bend machine process results in defective products, such as widened cut defects (cutting burr), bent cut defects (cutting bend), excessively long cuts (excess cutting), bent terminal defects (terminal bend), injured terminals (terminal damage), and broken drum core defects (drum core broken).

Widened cutting defect (cutting burr) occurs when the clearance between the punch and die plate is too large, resulting in burrs on the cut surface [1]. This defect also occurs if the die plate or punch is chipped. Bent cutting defect (cutting bend) arises when the die plate or punch is worn out, causing the cut result to bend downward. Excess cutting defect occurs when the pressure from the stripper plate on the upper plate is insufficient to press the workpiece (terminal), or when the die plate has become too thin (reaching its usage limit), causing the cut to extend excessively or shift. Bent terminal defect (terminal bend) is caused by dirt on the die plate, resulting in the terminal bending. Damaged terminal defect (terminal damage) occurs when the terminal pickup magnet (gripper transfer) does not properly place the terminal onto the lower plate, and the terminal receives pressure from the upper plate, leading to a hole in the terminal becoming damaged—typically widening, which causes issues in subsequent processes. Broken drum core defect (drum core broken) happens when the gripper transfer fails to accurately position the terminal on the lower base block, and the terminal receives pressure from the upper block, causing the drum core to break; sometimes the drum core breaks due to being cut. The broken drum core defect has the highest impact compared to the other types of defects [2].

Until now, there have been many unused die plates with a thickness of 13.50 mm that have been left over since the ccc 01 production line started operating in 2010. This prompted the idea of utilizing these unused 13.50 mm die plates. By modifying the stripper plate on the cross pieces cut machine block, it is expected that the service life of the existing die plates can be extended. It is also possible that the die plates can be reused for a certain period until they reach a lower usage limit, thereby reducing concerns about running out of spare parts. From a financial perspective, this would help the company save costs on future die plate reserves.

2. LITERATURE REVIEW

2.1. Proses Sheet Metal Forming

The automotive, electronics, and even heavy industries such as shipbuilding and aerospace use stamped parts. The sheet metal forming process produces sheet metal or metal plates. This sheet metal manufacturing process falls under the category of fabrication processes where the material is either cut or shaped to form sheet metal that serves as a workpiece. The final shape is determined by the punch, which applies pressure, while the die functions as a support to hold the workpiece in place during pressing [3].

The thickness of the material used to classify a workpiece as sheet metal is not precisely defined. Sheet metal typically has a thickness ranging from 0.006 to 0.25 inches. Thicker materials are referred to as "plate," while thinner ones are called "foil." Common materials used in sheet metal fabrication include aluminum, brass, bronze, copper, magnesium, nickel, stainless steel, steel, titanium, and zinc [4].

Sheet metal can be processed by cutting, bending, and pressing flat plates to conform to the die surface up to the stage of plastic deformation, which allows for the creation of new parts matching the die geometry [5].

Cutting materials (shearing, cutoff, or part-off processes) have the capability to create holes and slits in any two-dimensional geometric shape. The holes and slits produced from this process can either serve as raw materials for subsequent processes or as final desired products. Sheet metal fabrication using press-part systems is generally divided into two categories: cutting and forming [6].

2.2. RSM (Response Surface Methodology)

Response Surface Methodology (RSM), which combines mathematics and statistics, is used to develop models and evaluate a response influenced by several independent variables or factors x, in order to optimize that response [7]. The relationship between the response y and the independent variables x is expressed as:

$$Y = F(X_1, X_2, \ldots, X_k) + \varepsilon \qquad (1)$$

where:

Y = *response variable*

$\mathbf{X_i}$ = *independent variabel* / *factor* (i = 1, 2, 3,.., k)

ε = *error*

In this example, Figure (1.a) below shows a graph illustrating the relationship between the output response variable (Y) of a chemical process and two process variables, or independent variables, namely reaction time (X_1) and reaction temperature (X_2). Note that for each value of X_1 and X_2, the resulting Y value is affected, and it can also be observed that the response values form a surface lying above the temperature-time plane. In Figure (1.b), the response surface is shown in a two-dimensional temperature-time format. The temperature-time relationship connects all points that yield the same result, forming contour lines of the response, known as a contour plot.

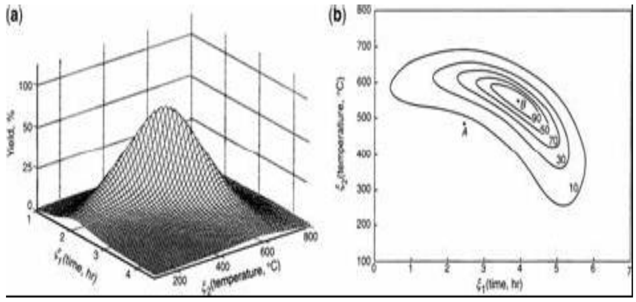

Figure 1. (a) Relationship between yield (Y) and reaction time (X_1) and temperature (X_2). (b) Contour plot.

By examining the plot, it was noted that the yield can be maximized at a reaction time of X_1 = 4 hours and a temperature of X_2 = 525ºC. Response Surface Methodology (RSM) consists of experimental strategies to explore the process space or independent variables (variables X_1 and X_2), and empirical statistical modeling to develop an accurate relationship between yield and the process variables, as well as optimization methods to find the levels or values of the process variables X_1 and X_2 that result in the desired response values (in this case, maximizing the yield) [8].

3. METHODOLOGY

Random sampling was used in this study, with one sample taken from the population elements for each observation. The data analysis used in this study is quantitative, with sampling conducted on the production line. The results of this sampling are collected as raw data, calculated, and then analyzed to determine the ideal values of the research variables.

Response Surface Methodology (RSM) uses mathematical and statistical techniques to analyze problems when multiple independent variables influence the dependent variable, with the goal of optimizing the response or output [9].

The stages of the Response Surface Methodology are as follows:

a) Selecting the factors that influence the response. This can be done using a general factorial approach.
b) Stage 2 involves forming a first-order regression model.
c) Stage 3 moves to the second-order regression model design if the first-order model does not yield ideal values. Next, the stationary points of the second-order regression model are sought to combine the input variable values that result in the ideal response.
d) Stage 4 determines the optimal system condition. The goal is to determine whether the optimal response value is a maximum or a minimum.

ANOVA (Analysis of Variance) is a statistical method used to test whether there are significant differences between the means of three or more data groups. In the context of engineering or industrial research, ANOVA is often used to evaluate the effect of independent variables on dependent variables, such as in the analysis of production process parameters. If the ANOVA test results show a significance value (p-value) less than 0.05, it can be concluded that at least one group has a significantly different mean, indicating that the variable has an effect on the observed outcome [10].

In applying ANOVA analysis, there are several basic requirements that must be met, namely: a) The data being analyzed should come from a distribution that is normal or approximately normal; b) Homogeneity of variances across populations must be present (homogeneity of variances); and c) ANOVA cannot be used for paired data because this method assumes that all samples are independent of one another. There are two main variants of ANOVA: one-way ANOVA and two-way ANOVA. One-way ANOVA is applied when each data group is influenced by only one factor, while two-way ANOVA is used when there are two or more factors affecting each data group [11]. In this study, data processing and testing were conducted using Minitab software version 16.

4. RESULTS AND DISCUSSION

4.1. Modification of the Stripper Plate

The stripper plate is an important component in the metal stamping process that functions to release the material that has been cut from the punch, while also holding the material in place during the cutting process. In this study, modifications were made to the stripper plate to improve the efficiency and quality of the cutting results.

The initial design of the stripper plate may not apply uniform pressure to the material, which could potentially cause defects such as burrs or deformation at the cut edges.

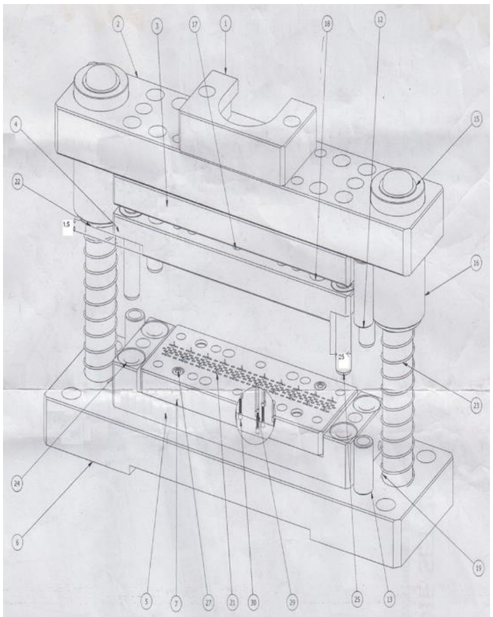

Figure 2. Die plate before modification.

The components of the cross pieces cut block can be seen in Table 1.

Table 1. Components of the cross pieces cut block.

Item	Qty	Part Number	Description
1	1	HOLDER	VEG-XPDS-001
2	1	PUNCH HOLDER	VEG-XPDS-002
3	1	PUNCH PLATE	VEG-XPDS-003
4	1	STRIPPER PLATE	VEG-XPDS-004
5	1	DIE HOLDER	VEG-XPDS-005
6	1	BASE BLOCK	VEG-XPDS-006
7	1	VEG DIE 20	VEG-XPDS-007
8	40	XPC PUNCH A	VEG-XPDS-008
9	40	XPC PUNCH B	VEG-XPDS-009
10	11	PARTING PUNCH A	VEG-XPDS-010
11	10	PARTING PUNCH B	VEG-XPDS-011
12	2	STROKE END BLOCK 1	VEG-XPDS-012
13	2	STROKE END BLOCK 2	VEG-XPDS-013
14	2	FIXING PLATE	VEG-XPDS-014
15	2	MBJH25-75	Misumi Ball Retainers for stripper
16	2	LBB25-80	Misumi Ball Bearing Guide Bushings
17	6	MSBB-25	Misumi Stripper bolts
18	4	SWR14.5-20	Misumi Coil Springs
19	2	MSP25-LC220	Misumi Guide post for die set
20	2	JP2-18.0-RC-HC2.8	Misumi Pushing pins
21	2	TPT1.6-18.5-P1.50-HC2.4-TKC	Misumi Straight Pilot Punches
26	2	RWB25	Misumi Anti Rise Rings
27	2	SWP25-150	Misumi Springs
32	4	SGHZ13-20	Misumi Stripper Guide Bushings
33	2	SGGWH13-LAC50-40-B10	Misumi Strong type stripper guide pins
34	4	SGBT13-16	Misumi Stripper guide bushings
35	4	MSTP8-25	Misumi Dowel pins
36	4	MSTP8-30	Misumi Dowel pins
37	2	MST-3	Misumi Wire Springs
38	20	MSW4	Misumi Screw plug

4.2. Data Adequacy Test Results

In this study, a confidence level of 99% and a precision level of 10% were used. The results of the data adequacy test for the variables of the stripper plate, punch, and air pressure can be seen in Table 2.

Table 2. Data Adequacy Test

Factor	$\sum X$	$\sum (X)^2$	N	N'	Exp.
Striper plate (mm)	380	7223,500	20	0,056	Adequate
Punch(mm)	841	35381	20	2,112	Adequate
Pressure or air pressure (Mpa*)*	8,85	3,947	20	0,003	Adequate

Based on the recap of the data adequacy test results above, the stripper plate, punch, and pressure are considered adequate because the value of N' is smaller than the value of N.

4.3. Results of Data Homogeneity Test

4.3.1. Data Homogeneity of Stripper Plate Parameter

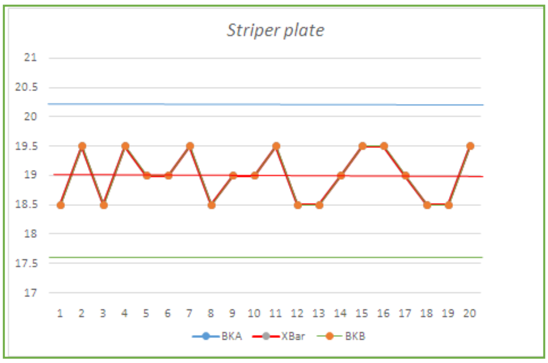

Figure 3. Control chart of stripper plate parameter.

The control chart above shows that the data used in this study is homogeneous because the data does not exceed the upper control limit or the lower control limit.

4.3.2. Data Homogeneity of Punch Parameter

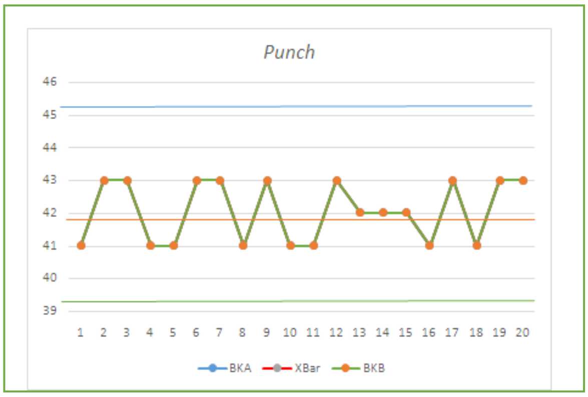

Figure 4. Control chart of punch length.

The control chart above shows that the data used in this study is homogeneous because the data does not exceed the upper control limit or the lower control limit.

4.3.3. Data Homogeneity of Pressure Parameter

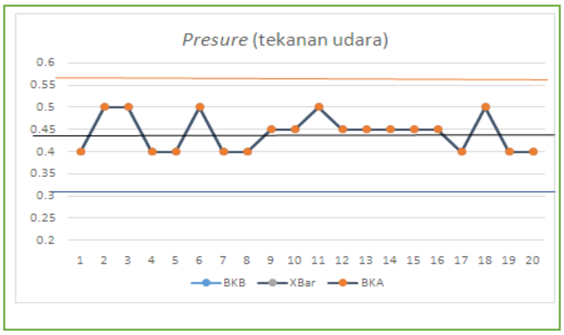

Figure 5. Control Chart of Pressure

The control chart above shows that the data used in this study is homogeneous because it does not exceed the upper or lower control limits.

4.4. Analysis

4.4.1. First-Order Analysis

The first-order model was developed as an initial approach to examine the influence on the response. As a preliminary step, an experimental design was prepared using a Central Composite Design (CCD) with three factors in Minitab 16 software. To facilitate the analysis, coding was applied to the independent variables and the response.

The experimental plan in this study includes a first-order model based on a factorial design of 3^3 + 6 center points, and a second-order model using a Central Composite Design (CCD) with a factorial design of 5^3 + 6 center points with varying factor levels.

Table 3. *Analysis of Variance (ANOVA) for Die Plate Life*

Analysis of Variance for Die Plate Life	*P-value*
Linear	0,897
Interaction	0,274
Lack-of-Fit	0,095

From **Table 3**, based on the results of the variance analysis above, a significance test or model adequacy test was conducted using ANOVA. This test uses a p-value < α. There are three parameters used to evaluate significance based on ANOVA in the first-order model: regression, which indicates the relationship or influence between independent variables and the response; lack of fit, which indicates the model's inadequacy; and curvature, which suggests that the linear model is not suitable due to the presence of curvature. All three parameters must be satisfied in order for the first-order model to be considered adequate and appropriate for analyzing the data in this study.

Using a significance level (confidence level) of 0.05, the regression yielded a p-value of 0.897, which is higher than the significance threshold. This means that the three independent variables cannot adequately represent the response. The analysis also showed model inadequacy or lack of fit. The lack of fit test begins by formulating the null hypothesis, which is:

H_0: There is no lack of fit; the model is appropriate and fits the data well.

H_1: There is a lack of fit; the model does not adequately represent the data.

The null hypothesis (H_0) will be rejected if the p-value is less than α (0.05). Conversely, the null hypothesis will be accepted if the p-value exceeds α (0.05). The analysis of variance shows that the p-value for the lack of fit test is 0.095, which is greater than α (0.05). Therefore, the decision is to accept H_0, indicating that the model fits the data well. The p-value for the interaction (curvature) is 0.274, which is also greater than α (0.05), indicating that the curvature has no significant effect.

Based on the analysis of variance in the first-order model, the regression equation is obtained as follows:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \varepsilon$$

$$= 61{,}465 - 0{,}065(X_1) + 0{,}065(X_2) + 0{,}893(X_3) + \varepsilon$$

$$= 61{,}465 - 0{,}065(19) + 0{,}065(42) + 0{,}893(0{,}45) + \varepsilon$$

4.4.2. Second-Order Analysis

In the second-order design, model estimation is carried out using a quadratic model. Since the first-order model was not able to provide sufficient information regarding the most influential factors on the response, the second-order design maintains the same factor levels as the first-order model, namely using the Central Composite Design (CCD) with a factorial of 5^3 plus 6 center points. Because the design used is a Central Composite Design, the factor levels in the second-order model are adjusted to five levels. Therefore, the value of 1.681 is included among the values used for coding the independent variables, which is calculated using the following equation:

$$X_{1,2,3} = \frac{n_{1-\text{middle value}}}{\text{difference between variables}/2}$$

Where n1 represents the actual values of the variables, Striper plate, Punch, and Pressure, the experimental encoding values on the second-order for variables X1, X2, and X3, as shown in Table 4.

Table 4. Second-Order Level Encoding

Factor Code	Factor	Level Code (-1.681)	(-1)	0	(1)	(1,681)
X1	*Striper plate (mm)*	18,20	18,50	19,00	19,50	19,80
X2	*Punch(mm)*	40,40	41,00	42,00	43,00	43,60
X3	*Pressure / Air pressure (Mpa)*	0,37	0,40	0,45	0,50	0,53

Table 5. *Analysis of Vvariance for die plate life*

Analysis of Variance for die plate life	*P-value*
Linear	0,316
Square	0,050
Interaction	0,097
Lack-of-Fit	0,180

Based on the results of the analysis of variance for the second-order model, the equation obtained is as follows:

$$Y' = 49{,}411 - 2{,}023(X_1) - 0{,}447\ (X_2 + 1{,}082(X_3) + 1{,}516(X_1)^2 + 2{,}993(X_2)^2 - 5{,}401(X_3)^2 - 1{,}511(X_1{*}X_2) - 2{,}583(X_1{*}X_3) + 1{,}735(X_2{*}X_3)$$

The testing of the results from the second-order model shows that the p-value for the regression as a whole is greater than $\alpha = 0.05$. This means that these three factors do not have a significant effect on the response. The lack of fit test is conducted in the same way as the lack of fit test in the first-order model. The p-value for the lack of fit test is greater than $\alpha = 0.05$, which is 0.180, indicating that the quadratic model in the second-order design used is appropriate. However, to check the adequacy or fit of the model in the second order, it is not only sufficient to look at the lack of fit, but also to conduct a residual test.

4.4.3. Residual Normality Test (Normality Test)

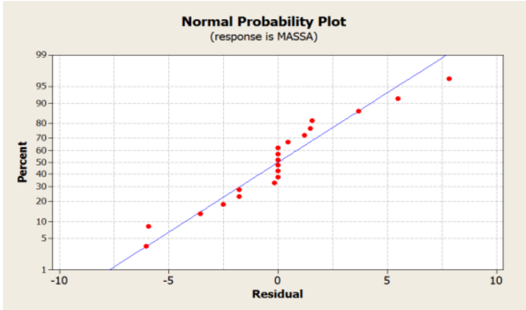

Figure 5. Residual Normality Test Curve of the Response Surface Model

The normality test is conducted to determine whether the residual points are normally distributed or not. A good regression model is one that has residuals that are normally distributed. The conclusion from the residual normality test is that the residuals of the created regression model follow a normal distribution. Therefore, the assumption of normality for the regression model created in the second order has been fulfilled and can be used.

4.4.4. Determination of the Optimum Point

After performing all statistical tests on the second-order model, the conclusion is that the second-order model is sufficient and appropriate to represent the model.

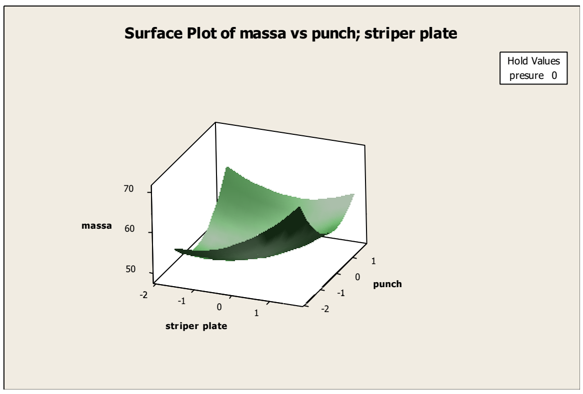

Figure 6. Surface Plot for Die Plate Thickness on Striper Plate and Punch

Based on the surface plot in Figure 6 above, the high die plate thickness response, reaching up to 70 hours and above, is obtained within the low striper plate range of 18.5 mm – 19 mm (or from level -1 to level 0) and the long punch range of 43 mm – 43.6 mm (or from level 1 to +1.681).

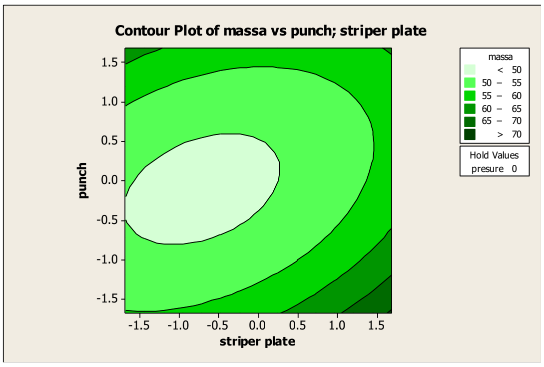

Figure 7. Contour Plot for Die Plate Life on Striper Plate and Punch

Based on the contour plot in Figure 7 above, the high die plate life response, reaching up to 65 hours and above, indicated by the dark green color, is obtained within the low striper plate thickness range of 18.5 mm – 19 mm (or from level -1 to level 0) and the long punch range of 43 mm – 43.6 mm (or from level +1 to +1.681).

The low die plate life response, below 50 hours and indicated by the white color, is obtained within the thick striper plate range of 19 mm – 19.5 mm (or from level 1 to level +1) and the short punch range of 40.4 mm – 41 mm (or from level -1.681 to -1).

Based on the surface plot in Figure 8 above, the high die plate life response, reaching up to 70 hours and above, is obtained within the short punch range of 41 mm – 42 mm (or from level -1 to level 0) and the high pressure range of 0.50 MPa – 0.53 MPa (or from level +1 to +1.681).

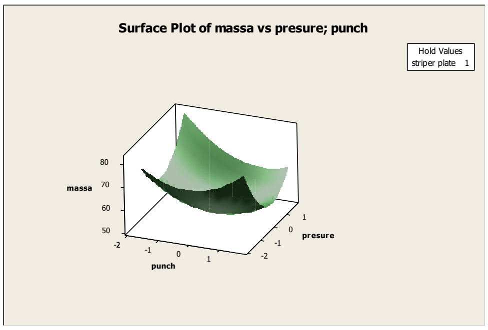

Figure 8. Surface Plot for Die Plate Life on Punch Length and Pressure

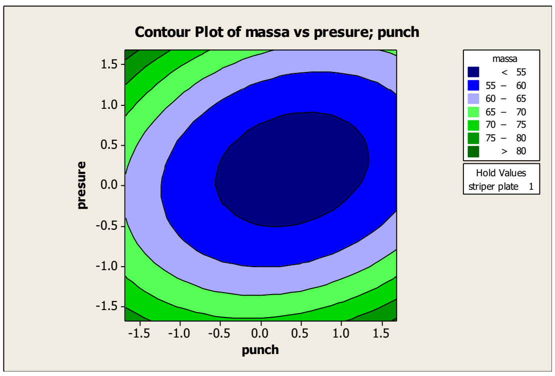

Figure 9. Contour Plot for Die Plate Life on Punch Length and Pressure

Based on the contour plot in Figure 9 above, the high die plate life response, reaching up to 80 hours and above, indicated by the dark green color, is obtained within the low punch length range of 41 mm – 42 mm (or from level -1 to level 0) and the high pressure range of 0.5 MPa – 0.53 MPa (or from level +1 to +1.681). The low die plate life response, below 55 hours and indicated by dark blue, is obtained within the high punch length range of 42 mm – 43 mm (or from level 0 to level +1) and the low pressure range of 0.37 MPa – 0.4 MPa (or from level -1.681 to -1).

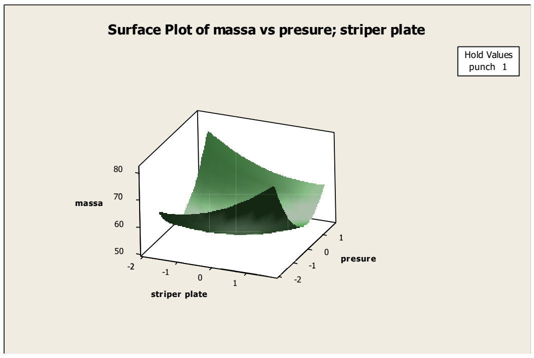

Figure 10. Surface Plot for Die Plate Life on Striper Plate and Pressure

Based on the surface plot in Figure 10 above, the high die plate life response, reaching up to 80 hours and above, is obtained within the low striper plate thickness range of 18.2 mm – 18.5 mm (or from level -1.681 to level -1) and the high pressure range of 0.5 MPa – 0.53 MPa (or from level +1 to +1.681).

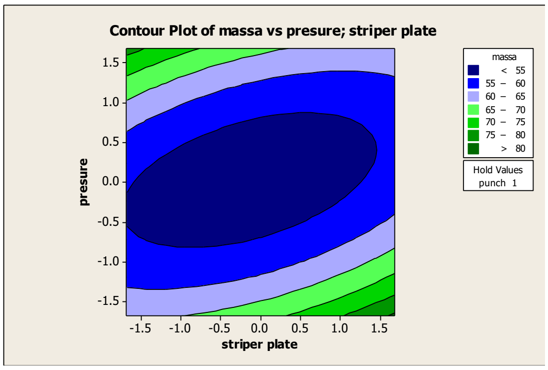

Figure 11. Contour Plot for Die Plate Life on Striper Plate and Pressure

Based on the contour plot in Figure 11 above, the high die plate life response, reaching 80 hours and above, indicated by the dark green color, is obtained within the low striper plate thickness range of 18.2 mm – 18.5 mm (or from level -1.681 to level -1) and the high pressure range of 0.5 MPa – 0.53 MPa (or from level +1 to +1.681). The low die plate life response, below 55 hours and indicated by dark blue, is obtained within the low striper plate thickness range of 18.2 mm – 18.5 mm (or from level -1.681 to level -1) and the low pressure range of 0.37 MPa – 0.4 MPa (or from level -1.681 to -1). To determine the optimum point, calculations are made in a matrix based on the coefficients in the second-order model equation.

Y'= 49,4114 – 2,0232(X1) – 0,4477(X2) + 1,0828(X3) + 1,5169(X1)^2 + 2,9933(X2)^2 – 5,4019(X3)^2 – 1,5117(X1.X2) – 2,5838(X1.X3) + 1,7353(X2.X3)

From the second-order model design equation above, a matrix is created as follows:

$$b = \begin{bmatrix} \beta_1 \\ \beta_2 \\ \beta_3 \end{bmatrix}, B = \begin{bmatrix} \beta_{11} & \beta_{12/2} & \beta_{13/2} \\ \beta_{12/2} & \beta_{22} & \beta_{23/2} \\ \beta_{13/2} & \beta_{23/2} & \beta_{33} \end{bmatrix}$$

$$b = \begin{bmatrix} 2{,}023 \\ -0{,}447 \\ 1{,}082 \end{bmatrix}, B = \begin{bmatrix} 1{,}516 & -0{,}755 & -1{,}291 \\ -0{,}755 & 2{,}993 & -0{,}867 \\ -1{,}291 & -0{,}867 & 5{,}401 \end{bmatrix}$$

$$C = \begin{bmatrix} 15{,}780 & 2{,}756 & -15{,}831 \\ -4{,}661 & 15{,}172 & 3{,}403 \\ 4{,}420 & 3{,}403 & 3{,}929 \end{bmatrix}$$

From the calculations of the matrix above, the actual values of the independent variables that result in the optimal response or optimal values are Striper plate (X1) = 19.13 mm, Punch length (X2) = 41.75 mm, and Pressure (X3) = 0.457 MPa.

5. CONCLUSION

Based on the results of the analysis and discussion of the optimization of the variables affecting the die plate service life obtained in this study, it can be concluded that the variables of striper plate thickness, punch length, and air pressure do not have a significant effect on the die plate service life.

REFERENCES

[1] A. A. Kamarul Adnan, S. N. Azinee, N. Norsilawati, and K. A. M. Izzul, "Analysis of the influence of the blanking clearance size to the burr development on the sheet of mild steel, brass and aluminium in blanking process," *J. Achiev. Mater. Manuf. Eng.*, vol. 111, no. 1, pp. 26–32, Mar. 2022, doi: 10.5604/01.3001.0015.9093.

[2] F. Akyürek, K. Yaman, and Z. Tekiner, "An Experimental Work on Tool Wear Affected by Die Clearance and Punch Hardness," *Arab. J. Sci. Eng.*, vol. 42, no. 11, pp. 4683–4692, Nov. 2017, doi: 10.1007/s13369-017-2621-0.

[3] R. Hambli, F. Guerin, and B. Dumon, "Numerical Evaluation of the Tool Wear Influence on Metal-Punching Processes," *Int. J. Adv. Manuf. Technol.*, vol. 21, no. 7, pp. 483–493, May 2003, doi: 10.1007/s001700300057.

[4] Schuler, *Metal forming handbook*. Springer Science & Business Media, 1998.

[5] L. Ulfiyah, F. Rohmah, and T. Permata, "Analisa Pengaruh Komposisi Cu dan Mg pada Paduan Al-Cu dan Al-Mg untuk Chassis Kendaraan," *J. Rekayasa Mesin*, vol. 12, no. 3, pp. 497–506, 2021.

[6] H. K. Tönshoff, C. Arendt, and R. Ben Amor, "Cutting of Hardened Steel," *CIRP Ann.*, vol. 49, no. 2, pp. 547–566, 2000, doi: 10.1016/S0007-8506(07)63455-6.

[7] F. Amir, B. A. Adietya, and M. Iqbal, "Anaslisa Optimasi Lambung Demihull Katamaran Menggunakan Response Surface Methode Pada Motion Sickness Incidence," *J. Tek. Perkapalan*, vol. 6, no. 1, pp. 1–9, 2018.

[8] O. Setiawan and A. T. Pradipta, "Penggunaan Metode Response Surface Methodology Box Behnken Untuk Pemodelan dan Optimasi Proses Fenton pada Pengolahan Limbah Cair Home Industri Sarung Tenun Tradisional Medangan Gresik," *METANA*, vol. 20, no. 2, pp. 97–107, Dec. 2024, doi: 10.14710/metana.v20i2.66413.

[9] M. A. Octaviani, D. R. S. Dewi, and L. J. Asrini, "OPTIMASI FAKTOR YANG BERPENGARUH PADA KUALITAS LILIN DI UD.X DENGAN METODE RESPONSE SURFACE," *J. Ilm. Widya Tek.*, vol. 16, no. 1, pp. 29–38, 2017.

[10] H. D. Siregar, M. Wassalwa, K. Janani, and I. S. Harahap, "Analisis Uji Hipotesis Penelitian Perbandingan menggunakan Statistik Parametrik," *Al Ittihadu*, vol. 3, no. 1, pp. 1–12, 2024.

[11] S. Dewi, R. Ermina, V. Kasih, F. Hefiana, A. Sunarmo, and R. Widianingsih, "ANALISIS PENERAPAN METODE ONE WAY ANOVA MENGGUNAKAN ALAT STATISTIK SPSS," *J. Ris. Akunt. Soedirman*, vol. 2, no. 2, pp. 121–132, 2023, doi: 10.32424/1.jras.2023.2.2.10815.