International journal of science, engineering, and information technology
Volume 09, Issue 02, December 2024
Journal homepage: https://journal.trunojoyo.ac.id/ijseit

The Analysis of Determining Ampere, Voltage And Interval Time Parameters in The FCAW Welding Process to Minimize Deformation Using Taguchi Method

Rohmat[a], Hidayat[b], Muhtadin[c]

[a]Universitas Muhammadiyah Lamongan, Lamongan, Indonesia
[b]Universitas Muhammadiyah Gresik, Gresik, Indonesia
[c]National Taiwan University of Science and Technology, Taipei, Taiwan

A B S T R A C T

Welding is an important process in manufacturing work to produce strong and durable joints. In the welding process, there are various parameters that are considered and used, especially in the FCAW welding process. In this study, several types of FCAW welding machine parameters used are ampere, voltage, and interval time of welding. The purpose of this study is to obtain the best welding quality results by combining these parameters by finding a comparison of the three parameters to minimize one of the welding defects, namely deformation. The method used is using DOE. This method allows to identify the parameters that most affect the quality of the weld and determine the optimal settings for each parameter. From the results of data processing and analysis, it was found that the voltage parameter was the most influential on deformation. The combination of levels in the predetermined parameters is ampere at level 1 with a number of 150 A, voltage at level 1 with a number of 22 V, and interval time at 10 minutes. The experimental data model has been tested with regression analysis to obtain an R-squared of 79.43%, and the residual plot analysis follows a straight line, so that the model is normally distributed and the statistical test results are significant, meaning that the observation data represents real data.

Keywords: FCAW, Welding, Welding Parameters, and Taguchi Method

Article History
Received 12 August 24 Received in revised form 10 October 24 Accepted 05 December 24

1. Introductions

The use of the FCAW welding method or process allows it to be applied in the on board or on block area, with a large volume of work compared to when using the SMAW welding method or process[1]. To further optimize the use of this FCAW welding method, a welder is required to be able to get a better variant of techniques or work methods. Because in this FCAW welding process there are welding parameters that will be used including ampere, voltage, and process interval time before welding aims to minimize one of the welding defects, namely freezing. One method that is suitable for solving this problem is to apply the Taguchi method. The Taguchi method is commonly used because it can achieve the number of experiments so that it can minimize time and costs and find out the optimal factors and levels for improving quality[2][3].

The result of the Taguchi method is a combination of factors and their levels that are robust to noise[4]. Therefore, the author gave the title to this study with the title analysis of determining ampere, voltage and interval time parameters in the FCAW welding process to minimize deformation using Taguchi method. The results of this study are expected to be able to define which welding parameters significantly affect the deformation. With this study, in the future it can be a reference and knowledge about the FCAW welding process and its applications, knowing the potential that can be developed for welding work in shipbuilding, and also as a consideration by using a new welding method in order to increase productivity and the best results

2. Methods and Materials

2.1 Welding Parameters

In this study, several types of FCAW welding machine parameters used are ampere, voltage, and interval of welding time. The following are the details of the parameters and levels used in this study, which can be seen in the Table 1.

Table 1. The Welding Parameters and *The* Levels

Parameters	Levels		
	1	2	3
Ampere	150 A	160 A	180 A
Voltage	22 V	26 V	28 V
Interval Time	3 mnt	10 mnt	15 mnt

2.2 Equipment and Workpiece

The specific equipment and workpiece used in this study can be seen

* *Corresponding Author*
E-mail address: rohmat.weld@umla.ac.id

E-ISSN 2548-4214

in Table 2.

Table 2. Equipment and Workpiece

Items	Specification
Workpiece	Steel with grade A, 8 mm of thigh, 300 mm of length, 150 mm of wide
Welding machine	FCAW (OTC XD 500)
Welding wire	Kiswel E71T-1C, 15 Kg of weight, Ø1,2 mm, TS 580 N/mm^2, YS 530 N/mm^2, 0.05% C, 0.5 Si, 1.30 Mn
Backing ceramics	WT101, 8 mm of gap

Using the same type of welding machine in each trial, namely the semi-automatic flux core arc welding (FCAW) welding machine. The welding machine used has been calibrated by the quality control (QC) team**.** The measuring tool used in calculating the speed in each welding process is the initial time (start) of welding to the end (stop) of welding only in second. The welding process only uses two layers, root pass and finishing**.** After the root pass is complete, cleaning will always be carried out using a grinder on the welding groove. The measurement of time in welding will be added up from the root pass and finishing processes in second**.** The deformation measuring tool uses thread and welding gauge in millimeters. The test piece illustration can be seen in the Figure 1.

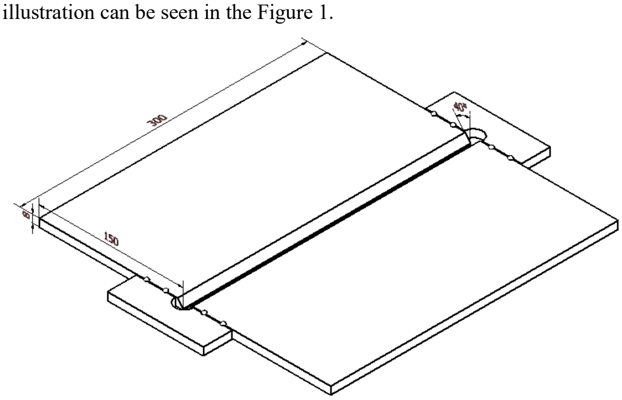

Figure 1. Test Piece Ilustration

3. Analysis of Results

3.1 Processing with Taguchi Method

In this study, all data processing with the Taguchi method will be carried out with the help of Minitab17 software. This is done to avoid errors in manual calculations. The level of time efficiency and effectiveness of using this software is also higher than manual. The combination design used for the Taguchi method used in this study is the L9 orthogonal array[5]. This design is used by considering the time and cost of the study.

3.2 S/N Ratio Calculation

From some this S/N ratio calculations, this research uses the quality characteristics of the Taguchi method with the smaller-the better[6][7]. This is applied because we are conducting research on the results of welding defects, namely deformation. The purpose of applying this characteristic is to obtain the minimum defects. So with formula no. 1 below, the following results are obtained[8]. Table 3. below will also present the results of observations, the results of the design of the combination of data collection, and the results of deformation measurements after welding.

The signal to noise ratio for the smaller the better $= -10\log\frac{1}{n}\sum(R)^2$ (1)

Where n is the observation number and R is each response in the data observation.

Table 3. Combination Design and Calculation Results of S/N Ratio

No. Exp.	Parameters			Deformation (mm)	Result of S/N ratio (dB)
	Ampere (A)	Voltage (V)	Interval time (minutes)		
1	150	22	3	1.07	-0.58768
2	150	26	10	1.05	-0.42379
3	150	28	15	2.07	-6.31941
4	160	22	10	1.06	-0.50612
5	160	26	15	2.05	-6.23508
6	160	28	3	2	-6.0206
7	180	22	15	1.08	-0.66848
8	180	26	3	2.02	-6.10703
9	180	28	10	3	-9.54243

3.3 Effect Plot of Welding Parameters on Deformation

After performing the S/N ratio calculation process, the next step is to create an effect plot to find out which parameters or factors have the most influence on deformation. From the results of the software processing, we get the plot in Figure 2.

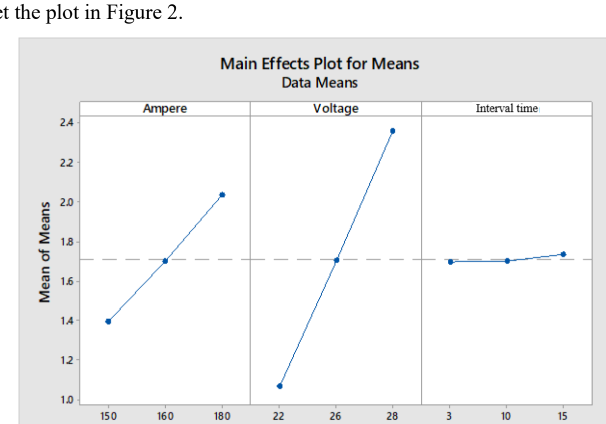

Figure 2. The Effect Plot of Welding Parameters in Deformation

From the main effects plot for means above, it can be seen that each parameter with the highest value is a parameter that has a large impact on deformation.

3.4 Selection of Optimum Parameters from Each Level to Minimize Deformation

This step will be done by looking at the plot and the results of the response table calculation on the S/N ratio. The selection of each optimum parameter is by choosing the largest value of each parameter value in the response table. Based on the Taguchi method, a higher S/N ratio reflects the smallest possible deviation between the desired and measured output. For clearer results on which parameters are optimal, it can be seen in Figure 3. on the S/N ratio plot below.

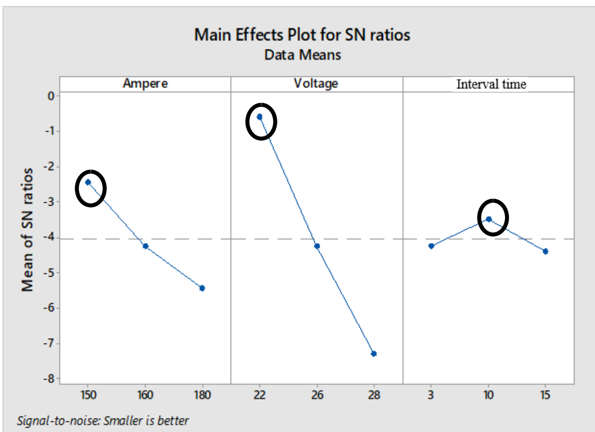

Figure 3. S/N Ratio Plot

The details of the value of each calculation result of the S/N ratio response on each parameter can be seen in table 4.

Table 4. Response Table for S/N Ratio (Smaller is better)

Levels	Welding Parameters		
	Ampere	Voltage	Interval time
1	**-2.4436**	**-0.5874**	-4.2384
2	-4.2539	-4.2553	**-3.4908**
3	-5.4393	-7.2941	-4.4077
Delta	2.9957	6.7067	0.9169
Rank	2	1	3

From the table above we can conclude that the ampere parameter at level 1, which is at 150 A. This is the optimal one to obtain the smallest deformation. For the voltage parameter at level 1, it is at 22 V. This is the optimal one to obtain the smallest deformation. For the interval time parameter at level 2, it is at 10 minutes. This is the optimal one to obtain the smallest deformation.

3.5 Determining the Most Influential Parameters on Deformation with ANOVA

ANOVA test is used to determine whether or not the findings of a survey or experiment are significant. ANOVA has a table that represents the survey values. By comparing the p-value for each term in the model to our significance threshold for testing the null hypothesis, we can determine whether the relationship between the response and each parameter in the model is statistically significant[4]. The null hypothesis is that there is no relationship between the parameter and the response. The level of significance is denoted by α. The level of significance is 0.05.

The hypothesis test conditions are as follows:

- If p-value <α (0.05): The correlation is statistically significant, which means the p-value is less than or equal to the significance level, therefore we can assume that the response variable and parameter have a significant correlation.
- If p-value > α (0.05): The correlation is statistically insignificant, which means the p-value is greater than or not equal to the significance level, therefore we should not assume that the response variable and parameter have a significant correlation.

From the research conducted by applying the cutting parameters designed with the Taguchi method L9 orthogonal array, the deformation is greatly influenced by voltage. This can be seen in the ANOVA table below by looking at the p-value.

Table 5. ANOVA

Source	DF	Adj SS	Adj MS	F	P
Reggression	3	2.98201	0.99400	6.44	0.036
Ampere	1	0.59109	0.59109	3.83	0.108
Voltage	1	2.38907	2.38907	15.47	**0.011**
Interval time	1	0.00186	0.00186	0.01	0.917
error	5	0.77208	0.15442		
Total	8	3.75409			

In the ANOVA table, the p-value of voltage is 0.011. This means that the correlation is statistically significant, because the p-value is less than the significance level. Therefore, we can assume that the response variable (deformation) and the parameter in this case voltage has a significant correlation.

3.6 Modeling

In this study, it was tested by applying linear regression analysis to Minitab17 software. The capability of the model created was evaluated using the coefficient of determination R-squared. The coefficient of determination value ranges from zero to one. If it approaches one, it indicates that the dependent and independent variables match. The regression model built for deformation in this study has an R-squared value of more than 70% (0.07) approaching 1, precisely at 79.43%. The coefficients in the projected model were checked for significance using a residual plot. If the residual plot is a straight line, then the model is normally distributed and the coefficient is significant. Figure 4.4 shows that the residuals approach a straight line, indicating that the coefficient model is significant.

Table 6. Results of R-squared Calculation

s	R-sq	R-sq (adj)
0.392957	79.43%	67.09%

Regression Equation:

$$\text{Deformation} = -6.90 + 0.0205\ \text{Ampere} + 0.2065\ \text{Voltage} + 0.0029\ \text{Interval time} \quad (2)$$

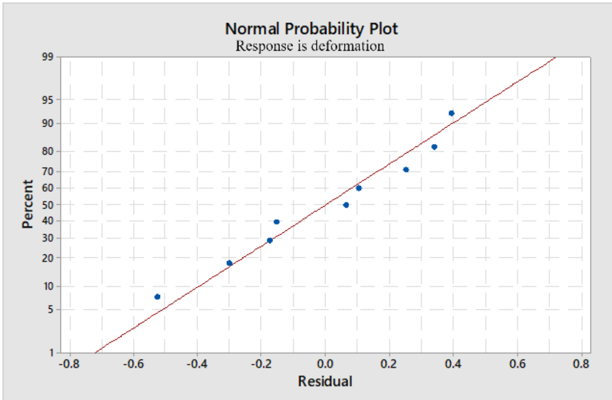

Figure 4. Probability Plot on Deformation

4. Conclusion

The conclusions that can be drawn from this study are as follows:

1. The combination design of the L9 orthogonal array Taguchi method experiment is the right combination design when we want to take samples in conditions of limited costs, time, and materials. This is because the number is not too many samples, but is still sufficient as a reference for taking samples.
2. In selecting the optimal parameters to minimize deformation, the ampere parameter at level 1, namely at 150 A, is the optimal one to get the smallest deformation. For the voltage parameter at level 1, namely at 22 V, it is the optimal one to get the smallest deformation. For the pause time parameter at level 2, namely at 10 minutes, it is the optimal one to get the smallest deformation.
3. By making a hypothesis and paying attention to the alpha value (0.05), the ANOVA table shows that voltage parameter is the most significant influence on deformation.
4. From the modeling results using regression analysis and residual plots, the data observation design and results are able to represent real or actual data.

Acknowledgements

The author would like to express the gratitude for the help or encouragement from colleagues involved in this research. This research would not have been possible without the help of the related parties. Hopefully, this research will have an impact on the science, and it can also be applied in the industrial field.

References

[1] R. A.Hadiguna andA.Ramadhianto, "Optimalisasi Parameter Teknik Pengelasan Shielded Metal Arc Welding (SMAW) dengan Menggunakan Metode Taguchi," *Pros. Semin. Nas. …*, pp. 860–869, 2023, [Online]. Available: https://ojs.uajy.ac.id/index.php/SENASTI/article/view/8016%0 Ahttps://ojs.uajy.ac.id/index.php/SENASTI/article/download/80 16/3262.

[2] N.Eslami, Y.Hischer, A.Harms, D.Lauterbach, andS.Böhm, "Optimization of process parameters for friction stir welding of aluminum and copper using the taguchi method," *Metals (Basel).*, vol. 9, no. 1, 2019, doi: 10.3390/met9010063.

[3] S.Reddy Vempati, K.Brahma Raju, andK.Venkata Subbaiah, "Optimization of Welding Parameters of Ti 6al 4v Cruciform shape Weld joint to Improve Weld Strength Based on Taguchi Method," *Mater. Today Proc.*, vol. 5, no. 2, pp. 4948–4957, 2018, doi: 10.1016/j.matpr.2017.12.072.

[4] U. .Esme, M. .Bayramoglu, Y. .Kazancoglu, andS. .Ozgun, "Optimization of weld bead geometry in TIG welding process using grey relation analysis and Taguchi method [Optimizacija geometrije TIG-varkov z greyjevo analizo in Taguchijevo metodo]," *Mater. Tehnol.*, vol. 43, no. 3, pp. 143–149, 2009, [Online]. Available: https://www.scopus.com/inward/record.uri?eid=2-s2.0-78650689480&partnerID=40&md5=a8a203bde9dc879209d190 86eecc709e.

[5] B.Shanmugarajan, R.Shrivastava, P.Sathiya, andG.Buvanashekaran, "Optimisation of laser welding parameters for welding of P92 material using Taguchi based grey relational analysis," *Def. Technol.*, vol. 12, no. 4, pp. 343–350, 2016, doi: 10.1016/j.dt.2016.04.001.

[6] P. Deshmukh andM.B. Sorte, "Optimization of Welding Parameters Using Taguchi Method for Submerged Arc Welding on Spiral Pipes," *Int. J. Recent Technol. Eng.*, vol. X, no. X, pp. 1–6, 2013, [Online]. Available: https://www.researchgate.net/publication/351249707.

[7] A.Balaram Naik andA.Chennakeshava Reddy, "Optimization of tensile strength in TIG welding using the Taguchi method and analysis of variance (ANOVA)," *Therm. Sci. Eng. Prog.*, vol. 8, no. July 2017, pp. 327–339, 2018, doi: 10.1016/j.tsep.2018.08.005.

[8] A.Daniel Das, S. N.Vijayan, andN.Subramani, "Investigation on welding strength of fsw samples using taguchi optimization technique," *J. Crit. Rev.*, vol. 7, no. 9, pp. 179–182, 2020, doi: 10.31838/jcr.07.09.36.