Optimization of Weld Bead Geometry for Cold-Rolled Thin Steel Plate Lap Joints using ColdArc Welding

RESEARCH ARTICLE

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The profile of weld bead geometry plays a vital role in establishing the joint quality of lap configurations. Refining these geometric attributes is crucial for maintaining the robustness of the structure, particularly within automotive applications. It remains challenging to join thin plates effectively by optimizing process parameters to achieve compatible joints. This study aims to examine the interaction between parameters by developing mathematical equations to predict the bead geometry in ColdArc welding. The experiments were set-up using ER70S-6 steel wire on cold-rolled structural workpieces. Shielding was provided by a gas mixture of 80% Argon and 20% CO_2 with a 1.0 mm diameter mild steel filler wire. A set of experiments was performed to collect data using the Central Composite Design (CCD) technique of Response Surface Methodology (RSM). A total of 20 experiments were conducted based on the RSM design. The results of the confirmation experiments demonstrated that the developed mathematical models could predict the bead geometry with reasonable accuracy. This study proved that interaction effects play a major role in determining bead dimensions. The process successfully minimized the bead width and bead height parameters using RSM.

1.Introduction

Weld bead geometry significantly influences the mechanical and metallurgical features of a weld, which are directly related to the welding process parameters. One of the qualities in the respected components depends on weld bead geometry and coefficient shape of welds and dilution (Biber et al., 2024). The process of depositing a thick layer of filler material on low carbon steel base metal/Weld bead geometry discovers new finding and applications in repairing worn out parts for achieving good corrosion resistant surface. Usually, this process is called surfacing technique in which relatively, thick coating for several millimeters were applied. Bead geometry is a surfacing technique that involves improvement of surface strength of mother metal which considerably to increase service life of the parent material without changing the microstructure of base material (Mondal et al., 2016). The mechanical and metallurgical feature of weld is depending on bead geometry which is directly related to welding process parameters (Wordofa et al., 2024).

Gas Metal Arc Welding (GMAW) remains a dominant technique for assembling metallic parts in the automotive sector (Basak et al., 2025). Recently, the light engineering industry has implemented more rigorous standards for welding operations, specifically regarding thin-gauge materials (Sabdin, Hussein, Sued, & Ayof, 2018). The prerequisites, which are progressively normal, and have turned out to be set up as objectives for new innovation innovative work (Kah et al., 2012; Zamzami et al., 2017). ColdArc is a variant of GMAW technology based on the short-circuiting transfer concept (Sabdin, Hussein, Sued, Manurung, et al., 2018; Sabdin, Izan, Hussein, Sued, et al., 2018a; Sabdin, Hussein, & Sued, 2019; Sabdin, Hussein, Sued, et al., 2019). Achieving narrow fabrication tolerances and improved weld quality are now standard requirements for new technological developments. Most researcher studied in order to enhance its chance for automation and to get good quality weld (Adamiec et al., 2017; Fronius, 2013; Korzeniowski et al., 2013). Reliability on mechanical properties of the weld metal, metallurgical characteristics and chemical composition of the weld to ensure the quality of a weld structure. This process is characterized by significantly reduced heat input, which is essential for welding thin-walled automotive steels without causing excessive distortion or burn-through (Goecke, 2005; Kah & Martikainen, 2012).

Response Surface Methodology (RSM) is an effective optimization technique used to determine the desired weld bead geometry. By using regression analysis and graphical methods, RSM helps determine the optimal welding

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process model (Kiaee & Aghaie-Khafri, 2014; Srivastava & Garg, 2017a, 2017b). Researchers mentioned RSM provides good results over regular experimental regions, or with no irregular points (Biber et al., 2024)(Correia et al., 2004; Myers, 2012; Said et al., 2015). Researcher Sahil Angaria et al (Angaria et al., 2017) Studies application of RSM in the central composite design to perform optimize hardness in GMAW experiments and shows significant results.

The objective of this study is to investigate the effect of current, voltage, and welding speed on the bead geometry of thin-plate cold-rolled steel joints welded using the ColdArc method. Unlike conventional surfacing or cladding techniques that deposit thick layers for wear resistance, this research focuses on lap-joint welding optimization for thin-sheet applications. Mechanisms related to the improvement of weld bead size and shape were investigated by focusing on welding parameters established through the Central Composite Design (CCD) method.

2. Materials and Methods

2.1 Materials

Cold-rolled steel plates (SPCC) with thicknesses of 0.8 mm and 1.0 mm were used shown in Table 1. It is a cold rolled sheet commonly referred as a commercial quality of cold rolled steel sheets (Park et al., 2017).

2.2 Design of Experiments

This investigation focused on three primary variables welding current (A), arc voltage, and travel speed (WS), each evaluated across three distinct levels. A Central Composite Design (CCD) was employed with axial points (α) account for values outside the standard low/high ranges. The design matrix comprises of full replication of $2^4 = 16$, Factorial designs. All welding parameters in levels define is in cube points and combination of each welding parameters at either is highest value (+1) or lowest (-1) in Table 2. Total numbers of 20 experiments were conducted that create estimation of linear, quadratic and two-way interactive effects of process parameters on weld bead geometry in Table 3.

Table 2. The selection of response and variable in the experimental design

Factors	Level	
	Low (-1)	High (+1)
Ampere (A)	32	48
Voltage (V)	6.50	14.50
Welding speed (mm/min)	350	750

Table 3. Design Matrix

Experiment Run	Current (A)	Voltage (V)	Welding speed (mm/min)
1	40.00	3.77	550
2	32.00	6.50	750
3	48.00	6.50	750
4	40.00	10.50	890
5	26.55	10.50	550
6	32.00	6.50	350
7	32.00	14.50	750
8	40.00	10.50	550
9	40.00	10.50	550
10	40.00	10.50	550
11	40.00	10.50	550
12	40.00	10.50	550
13	40.00	10.50	550
14	48.00	6.50	350
15	48.00	14.50	750
16	53.45	10.50	550
17	40.00	17.23	550
18	32.00	14.50	350
19	40.00	10.50	210
20	48.00	14.50	350

Table 1. Chemical composition of the cold-rolled material

Elements	C	Si	Mn	P	S	Cr	Mo	N	Al	Cu	Co	Fe
Cold Rolled	0.045	0.009	0.2	0.01	0.006	0.006	0.006	0.013	0.051	0.013	0.024	Bal.

3. Experimental Setup

A lap joint geometry was selected for the steel specimens to facilitate a more straightforward welding process using the robotic ColdArc system. This specific configuration was implemented to accommodate the maneuverability of the GMAW robotic arm during the welding operation (Germany: EWM, model: alpha Q 352 pulse) (Sabdin, Izan, Hussein, Sued, et al., 2018b) . Table 4 shows dimensions of each plate were set up in these experiments. The study utilized an ER70S-6 filler wire with a diameter of 1.0 mm, known for delivering consistent arc stability and a high-quality surface finish (Sabdin et al., 2017; Sabdin, Hussein, 2018, & 2018, 2018; Sabdin, Izan, Hussein, Sued, et al., 2018a). This mild steel wire is a high-performance filler material, especially for robotic or mechanized welding, and it is commonly used for construction, shipbuilding, automotive parts and fabrication (Nazir, 2023). It can produce smooth and constant arc with low spatter and produce smooth surface finish in the weld bead. Figure 1 shows the schematic of the weld bead geometry measurement. The results obtained was then analyzed using Minitab® Statistical Software version 17.

Table 4: Material Setup

Materials	Size	Represent
Cold Rolled	250 mm x 50 mm x 0.8 mm	Plate 1
Cold Rolled	250mm x 50 mm x 1mm	Plate 2

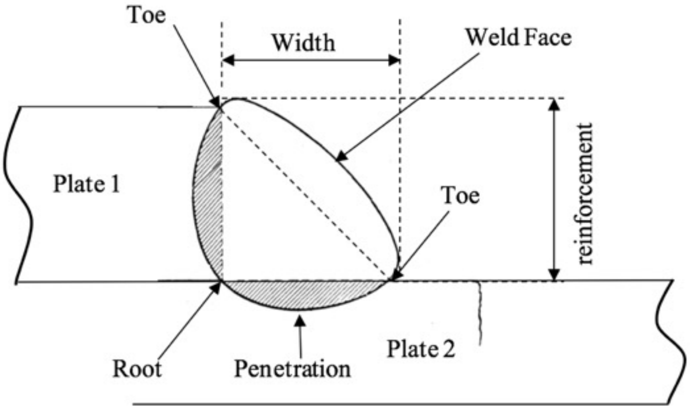
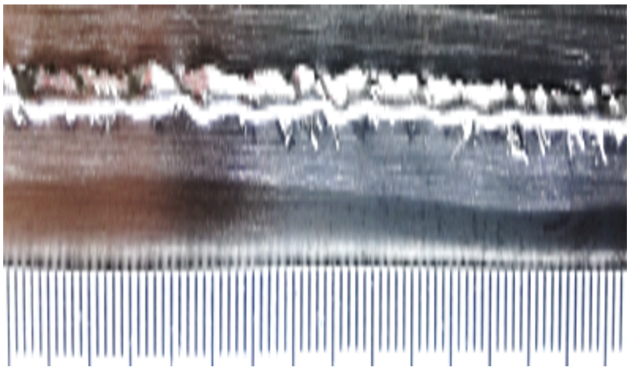


Figure 1. Weld bead geometry

4. Results and Discussion

Figure 2 shows two samples of photographs of welded resulting ColdArc weld of lap joint of cold rolled plates. Overall, the welding process produced joints with negligible levels of spatter. Data analysis Table 5 revealed that the maximum bead width reached 2.1 mm in run 19, whereas the minimum width of 1.55 mm was recorded in sample 2. The height weld was obtained at sample 1 at 1.83 mm and lowest at sample 20 is 1.15 mm. Average width and height weldment geometry size is 1.88 mm and 1.75 mm.



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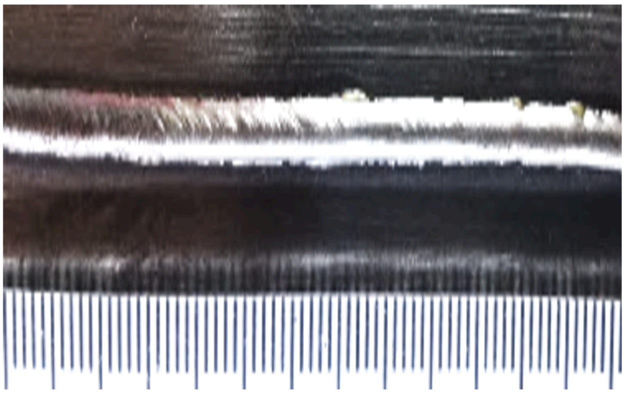

(b)

Figure 2. Sample photographs of the welded joints for a) sample 1 and, b) sample 2

Table 5. The results for experimental design

Run	Current (A)	Voltage (V)	Welding speed (mm/ min)	Bead size	
				Width (mm)	Height (mm)
1	40.00	3.77	550	1.6	1.83
2	32.00	6.50	750	1.55	1.62
3	48.00	6.50	750	1.64	1.5
4	40.00	10.50	890	1.63	1.48
5	26.55	10.50	550	1.67	1.5
6	32.00	6.50	350	1.72	1.47
7	32.00	14.50	750	1.73	1.4
8	40.00	10.50	550	1.8	1.46
9	40.00	10.50	550	1.81	1.4
10	40.00	10.50	550	1.84	1.38
11	40.00	10.50	550	1.9	1.33
12	40.00	10.50	550	1.8	1.35
13	40.00	10.50	550	1.83	1.47
14	48.00	6.50	350	1.82	1.41
15	48.00	14.50	750	1.9	1.43
16	53.45	10.50	550	1.94	1.39
17	40.00	17.23	550	1.98	1.3
18	32.00	14.50	350	2	1.28
19	40.00	10.50	210	2.1	1.22
20	48.00	14.50	350	2	1.15

4.1 Analysis of Variance (Anova)

The ANOVA technique was employed to quantify the individual contributions of each welding parameter toward the total variation in the response. This statistical method serves as a primary tool for evaluating the significance and impact of each input variable on the final weld quality. Model reliability was confirmed by a non-significant "Lack of Fit" value, suggesting that the mathematical equations are suitable for predicting the experimental outcome. In this study, the significance of welding parameters of current, voltage and welding speed were determined using Minitab® Statistical Software version 17.

4.2 Mathematical Mode1: Regression Analysis Bead Width

The analysis of variance results for response surface cubic model for bead width is given in table 6. The ANOVA results for the bead width and bead height models showed high significance with F-values of 54.91 and 8.82, respectively. The "Lack of Fit" was not significant, indicating the models are reliable for navigating the design space. Values of "Prob > F" less than 0.05 indicates that model terms are significant (Srivastava & Garg, 2017a). There is only 0.01% chance that large F-Value could occur due to noise. Values greater than 0.1 indicates the model terms are not significant (Prabaharan et al., 2014). If there are many insignificant model terms, model reduction may improve the model. The "Lack of Fit F-value" of 1.93 shows that lack of fit is not significant relative to the pure error. There is a 24.19% chance that large F − lack of fit value could occur due to noise(Kiaee & Aghaie-Khafri, 2014).

Table 6. ANOVA table for Bead width (BW)

Source	Sum of Squares	df	Mean Square	F-value	p-value	
Model	0.3890	3	0.1297	54.91	< 0.0001	significant
A-current	0.0485	1	0.0485	20.55	0.0003	
B-voltage	0.1734	1	0.1734	73.44	< 0.0001	
C-welding speed	0.1671	1	0.1671	70.73	< 0.0001	
Residual	0.0378	16	0.0024			
Lack of Fit	0.0306	11	0.0028	1.93	0.2419	not significant
Pure Error	0.0072	5	0.0014			
Cor Total	0.4268	19				

Table 7 shows Pred. R-squared" of 0.8521 is in sensible agreement with the 'Adj. R-squared' of 0.8949. "Adq precision" quantifies the signal to noise ratio. A ratio greater than 4 is desirable (Prabaharan et al., 2014). But here the value of "Adeq precision" is 26.0337 that indicates an adequate signal. Therefore, this model can be used to navigate the design space. The graph of predicted bead width and actual bead width is shown in Figure 3.

Table 7. Model Summary Statistic of BW

Std. Dev.	0.0486	**R^2**	0.9115
Mean	1.81	**Adjusted R^2**	0.8949
C.V. %	2.68	**Predicted R^2**	0.8521
Press	0.0631	**Adeq Precision**	26.0337

The mathematical model for the bead width response was developed using multiple linear regression, given by the equation (1):

$$\text{Bead Width} = \beta_0 + \beta_1 A + \beta_2 B - \beta_3 C \qquad (1)$$

In equation 1, in which Bead width is the responses value and β0 is the value for the intercept represent the average of all actual responses. While β1, β2 and β3 is the coefficient of factor A, B and C their interaction. The final equation is given by equation 2:

$$\text{Bead width} = 1.523 + 0.0075\,A + 0.0282B - 0.5529C \qquad (2)$$

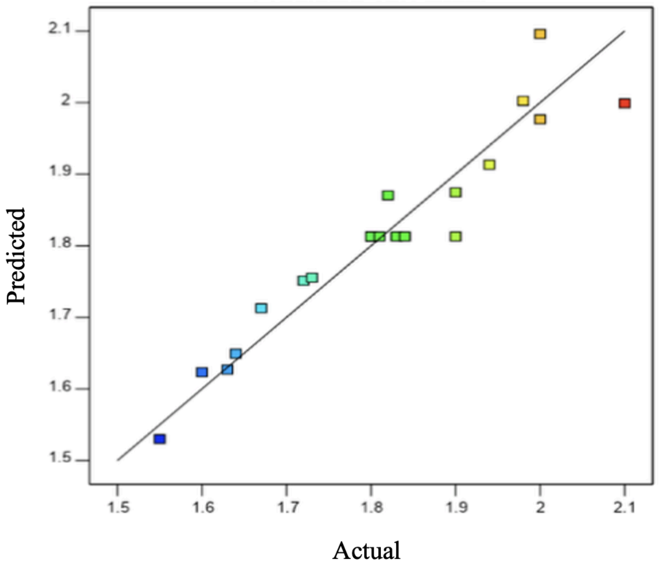

Figure 3. Predicted vs Actual bead width

4.3 Mathematical Model: Regression Analysis Bead Height

Table 8 shows indicated model F with significant 8.82 value. Value of "Prob > F" less than 0.05 indicates that model terms are significant (Srivastava & Garg, 2017a). There is only 0.01% chance that large F-Value could occur due to noise. Values greater than 0.1 indicates the model terms are not significant (Saini et al., 2024)(Prabaharan et al., 2014). If there are many insignificant model terms, model reduction may improve the model. The "Lack of Fit F-value" of 1.71 shows that lack of fit is not significant relative to the pure error. There is a 28.52% chance that large F − value of lack of fit could occur due to noise(Kiaee & Aghaie-Khafri, 2014).

The given Table 9 shows Pred. R-squared" of 0.3812 is in sensible agreement with the 'Adj. R-squared' of 0.7875. "Adeq precision" quantifies the signal to noise ratio. A ratio greater than 4 is desirable (Prabaharan et al., 2014). But here the value of "Adeq precision" is 12.0474 that indicates an adequate signal. Therefore, this model can be used to navigate the design space. The graph of predicted bead height and actual bead height is shown in Figure 4.

Table 8. ANOVA table for Bead Height

Source	Sum of Squares	df	Mean Square	F-value	p-value	
Model	0.3503	9	0.0389	8.82	0.0011	significant
A-current	0.0158	1	0.0158	3.59	0.0875	
B-voltage	0.1949	1	0.1949	44.16	< 0.0001	
C-welding speed	0.0850	1	0.0850	19.26	0.0014	
AB	0.0008	1	0.0008	0.1813	0.6793	
AC	0.0012	1	0.0012	0.2833	0.6062	
BC	0.0032	1	0.0032	0.7252	0.4144	
A^2	0.0005	1	0.0005	0.1224	0.7337	
B^2	0.0340	1	0.0340	7.70	0.0196	
C^2	0.0109	1	0.0109	2.46	0.1476	
Residual	0.0441	10	0.0044			
Lack of Fit	0.0278	5	0.0056	1.71	0.2852	not significant
Pure Error	0.0163	5	0.0033			
Cor Total	0.3945	19				

Table 9 shows Pred. R-squared" of 0.8521 is in sensible agreement with the 'Adj. R-squared' of 0.8949. "Adq precision" quantifies the signal to noise ratio. A ratio greater than 4 is desirable (Prabaharan et al., 2014). But here the value of "Adeq precision" is 26.0337 that indicates an adequate signal. Therefore, this model can be used to navigate the design space. The graph of predicted bead width and actual bead width is shown in Figure 3.

Table 9. Model Summary Statistic of Bead Height

Std. Dev.	0.0664	**R²**	0.8881
Mean	1.42	**Adjusted R²**	0.7875
C.V. %	4.68	**Predicted R²**	0.3812
Press	0.2441	**Adeq Precision**	12.0474

Mathematical model : Regression analysis of Bead height Quadratic equation represent by :

$$\text{Bead Height} = \beta_0+\beta_1A+\beta_2B-\beta_3C+\beta_4AB+\beta_5AC+\beta_6BC+\beta_7A^2+\beta_8B^2-\beta_9C^2 \quad (3)$$

In equation 3, in which Bead Height is the responses value and β_0 is the value for the intercept represent the average of all actual responses. While β_1, β_2, β_3, β_4, β_5, β_6, β_7, β_8 and β_9 is the coefficient of factor A, B and C their interaction. The final Mathematical model equation in terms of coded factors were as follows:

$$\text{Bead Height} = 2.39422-0.019488A-0.119835B + 0.57468C + 0.000312AB + 0.007812AC + 0.025000BC + 0.000096A^2 + 0.003034B^2 -0.686610C^2 \quad (4)$$

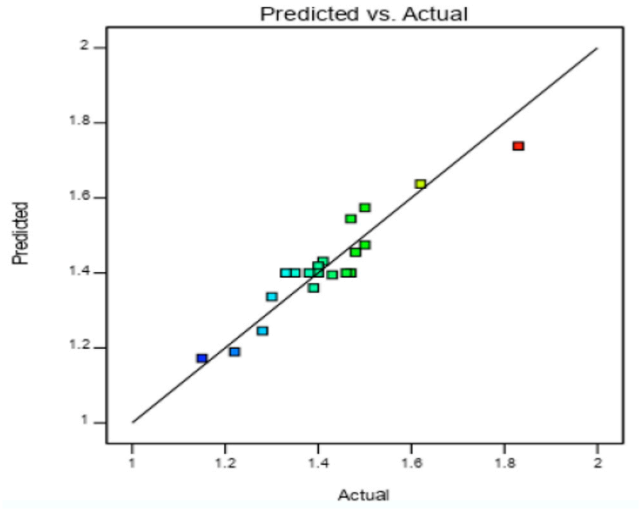

Figure 4. Predicted vs Actual Bead height

4.4 Optimization of Results

The optimized results are given in Table 10 with their desirability. Analysis of the desirable solutions indicated that the first experimental run achieved the highest desirability rating for the target responses in Table 11 (Kiaee & Aghaie-Khafri, 2014; Vedrtnam et al., 2018). Beyond identifying single optimal points for bead dimensions, the Response Surface Methodology (RSM) provided a comprehensive range of ideal operating parameters. The generated surface plots illustrate the complex relationships between input variables on the Z-axis, aiding in the visualization of the optimization landscape. The optimum values of bead width and bead height is shown in the response curves in Figure 5 and 6 respectively. RSM is a technique for optimization of process parameters. By using RSM plots, it is easy to optimize welding process variables to achieve most favorable bead geometries i.e., bead height, bead width and depth of penetration. In the surface plots shown in Figure 5 and 6, 7 two parameters are shown on X and Y axes, and the responses are shown on Z axis.

Table 10: Process Parameter & Response Constraint

Name	Goal	Lower Limit	Upper Limit	Lower Weight	Upper Weight	Importance
A: current	is in range	32	48	1	1	3
B: voltage	is in range	6.5	14.5	1	1	3
C: welding speed	is in range	0.35	0.75	1	1	3
Bead Width	minimize	1.6	3.5	1	1	3
Bead Height	minimize	1.65	3	1	1	3

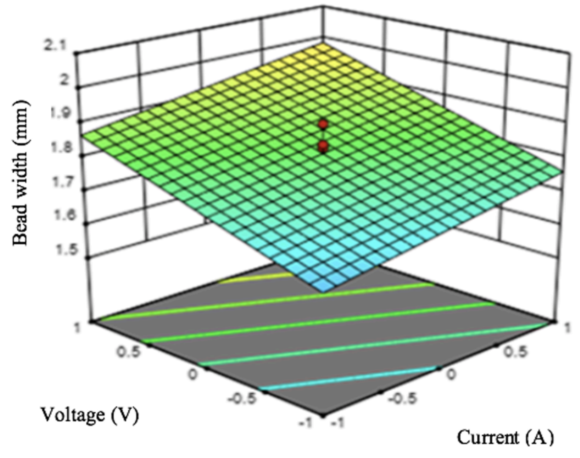

Figure 5. Response graph surface methodology effect Voltage and current on Bead Width

4.5 Confirmation Test

The optimized parameters have been verified by conducting confirmatory tests. For confirmatory test, new set of process parameters were considered for welding. Physically, the reduced heat input of the ColdArc process minimizes the melting of the base metal, which is crucial for maintaining the geometry of thin lap joints in Figure 7. The interaction between current and voltage was found to be the most influential factor in determining bead dimensions. Weldment area and the test results are compared to the predicted values as given in Table 12. Validation of the optimized settings showed that the discrepancy between the theoretical predictions and experimental observations was below 2%. Since the recorded error falls within an acceptable statistical margin, the established models are proven to be highly reliable for achieving minimal bead height and width (Srivastava & Garg, 2017b). Physical measurements of the confirmed weld samples demonstrated that the low heat input characteristic of ColdArc is vital for preserving the structural integrity of thin plates.

Table 12. Comparative results of conformity test

No	Parameter	Optimized parameter (predicted values)	Experimentally observed values	% error
1	Current (A)	32	32	-
2	Voltage (V)	6.5	6.5	-
3	Welding speed (m/min)	0.75	0.75	-
4	Bead Width (mm)	1.530	1.55	1.307
5	Bead Height (mm)	1.637	1.62	1.038

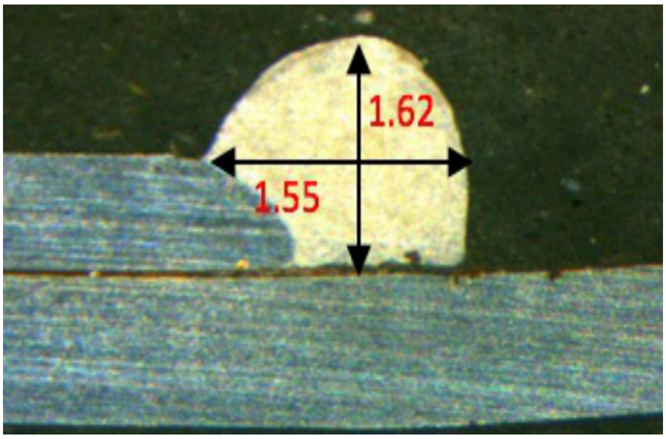

Figure 7. Weld bead confirmation by experimental observed value.

5. Conclusions

In general, it was found that dissimilar SPCC steel plates in lap joint configuration can be successfully welded using the ColdArc technology. The weldment result was consistent with minimal spatter levels. Experiments were done on basis of central composite design technique. Recorded data were used to find out optimal bead geometry i.e. bead height, bead width and depth of penetration. The following conclusions can be drawn from this study:

1. ColdArc technology using the GMAW platform can successfully weld dissimilar cold-rolled mild steel sheets in a lap joint configuration with minimal spatter.
2. The application of Response Surface Methodology (RSM) proved to be an efficient and practical approach for identifying optimal welding settings to achieve minimal bead dimensions.
3. Among the variables analyzed, the interplay between welding current and voltage emerged as the most significant factor affecting the results.
4. The optimized results were validated through confirmation tests, with error rates of less than 2%, proving the models are reliable.
5. Future research should explore the metallurgical properties and fatigue life of these thin-sheet joints to further enhance automotive manufacturing quality.

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References

Adamiec, J., Pfeifer, T., & Rykała, J. (2017). Modern methods of aluminum alloys welding. 176(2011), 35–38. https://doi.org/10.4028/www.scientific.net/SSP.176.35

Angaria, S., Rao, P. S., & Dhami, S. S. (2017). Application of RSM to Optimize MIG welding Process Parameters for Hardness. International Journal of Emerging Technologies in Engineering Research, 5(9), 31–36.

Basak, S., Khansole, A., & Ghosh, A. (2025). Advances in Arc Welding Process. In B. Acherjee, D. Zhao, & F. A. O. Fernandes, Advanced Welding Technologies (1st ed., pp. 1–40). CRC Press. https://doi.org/10.1201/9781003499688-1

Biber, A., Sharma, R., & Reisgen, U. (2024). Robotic welding system for adaptive process control in gas metal arc welding. Welding in the World, 68(9), 2311–2320. https://doi.org/10.1007/s40194-024-01756-y

Correia, D. S., Gonçalves, C. V., Sebastião, S. C., & Ferraresi, V. A. (2004). GMAW Welding Optimization Using Genetic Algorithms. Journal of the Brazilian Society of Mechanical Sciences and Engineering, 26(1), 28–33. https://doi.org/10.1590/s1678-58782004000100005

Fronius. (2013). CMT : Cold Metal Transfer A hot & cold process makes.

Goecke, S. F. (2005). Low Energy Arc Joining Process for Materials Sensitive to Heat. In EWM HIGHTEC WELDING GmbH.

Kah, P., & Martikainen, J. (2012). Current Trends In welding Processes And Materials: Improve In effectiveness. Rev. Adv. Mater. Sci., 30, 189–200.

Kah, P., Suoranta, R., & Martikainen, J. (2012). Advanced gas metal arc welding processes. International Journal of Advanced Manufacturing Technology. https://doi.org/10.1007/s00170-012-4513-5

Kiaee, N., & Aghaie-Khafri, M. (2014). Optimization of gas tungsten arc welding process by response surface methodology. Materials and Design, 54, 25–31. https://doi.org/10.1016/j.matdes.2013.08.032

Korzeniowski, M., Piwowarczyk, T., Kustroń, P., & Czubak, A. (2013). Low-Energy Welding Methods Used For Semi-Automatic Thin-Walled Automotive Steels. Advances in Materials Science, 13(3), 17–25. https://doi.org/10.2478/adms

Mondal, A., Saha, M. K., Hazra, R., & Das, S. (2016). Influence of heat input on weld bead geometry using duplex stainless steel wire electrode on low alloy steel specimens. Cogent Engineering, 3(1), 1–14. https://doi.org/10.1080/23311916.2016.1143598

Myers, W. (2012). Response Surface Methodology. In Encyclopedia of Biopharmaceutical Statistics, Third Edition (Issue May). https://doi.org/10.1201/b14674-189

Nazir, D. S. (2023). Latest Developments in MIG Welding—A Review. International Journal for Research in Applied Science and Engineering Technology, 11(6), 1138–1141. https://doi.org/10.22214/ijraset.2023.53791

Park, J., Kang, M., Sohn, S. S., Kim, J. S., Kim, H. S., Cho, W. T., & Lee, S. (2017). Tensile properties of cold-rolled TWIP-cored three-layer steel sheets. Materials Science and Engineering A, 686(November 2016), 160–167. https://doi.org/10.1016/j.msea.2017.01.046

Prabaharan, C., Venkatachalam, P., Suresh Kumar, K., & Lenin, K. (2014). Parametric optimization of gas tungsten arc welding processes by using factorial design approach. Journal of Scientific and Industrial Research, 73(6), 415–420.

Sabdin, S. D., Hussein, N., 2018, M. S.-… R. D., & 2018, U. (2018). Weld bead reinforcement on cold rolled carbon steel sheet joint using ColdArc technology. Proceedings of Mechanical Engineering Research Day 2018, 2018(May), 197–198

Sabdin, S. D., Hussein, N. I. S., & Sued, M. K. (2019). A Review on Thin Plates Joining Method Using Arc Welding as The Heat Sources. Journal of Industry, Engineering and Innovation, 1(2), 1–6.

Sabdin, S. D., Hussein, N. I. S., Sued, M. K., Ayob, M. S., M.Fadzil, & Rahim, M. A. S. A. (2019). Effects of ColdArc welding parameters on the tensile strengths of high strength steel plate investigated using the Taguchi approach. Journal of Mechanical Engineering and Sciences, 13(2), 4846–4856. https://doi.org/10.1017/CBO9781107415324.004

Sabdin, S. D., Hussein, N. I. S., Sued, M. K., & Ayof, M. N. (2018). Joining of Thin Plates using Various Arc Welding Heat Sources – A Review. Journal of Advanced Manufacturing Technology, Vol 12, 20(iDECON 2016), 357–370.

Sabdin, S. D., Hussein, N. I. S., Sued, M. K., Manurung, Y. H. P., & Jamaluddin, M. F. (2018). Numerical modelling verification of temperature distribution in ColdArc welding of thin plate. International Journal of Engineering & Technology, 7(4.36), 1569–1573.

Sabdin, S. D., Izan, N., Hussein, S., & Sued, M. K. (2017). Parameters and properties relationship of thin steel plate joint using low energy arc welding. Proceedings of Innovative Research and Industrial Dialogue 2016, 2017(1), 169–170.

Sabdin, S. D., Izan, N., Hussein, S., Sued, M. K., Ayof, M. N., & Shah, M. A. (2018a). The effect of voltage on weldment size cold rolled steel sheet joint using low arc joining technology. Proceedings of Innovative Research and Industrial Dialogue 2018, (July), 1–2.

Sabdin, S. D., Izan, N., Hussein, S., Sued, M. K., Ayof, M. N., & Shah, M. A. (2018b). The effect of voltage on weldment size cold rolled steel sheet joint using low arc joining technology. Proceedings of Innovative Research and Industrial Dialogue 2018, (July), 1–2.

Said, K. A. M., Yakub, I., & Amin, M. A. M. (2015). Overview of Response Surface Methodology (RSM) in Extraction Process. Journal of Applied Science & Process Engineering, 2(April), 279–287. https://doi.org/10.3850/978-981-09-4587-9_p38

Saini, A., Rehalia, V., Talgotra, A., & Shobit. (2024). Design and Assessment of Automatic Arc Welding Machine Based on Programming Logic Controller. International Journal of Engineering and Management Research, 14(6), 31–37. https://doi.org/10.31033/ijemr.14.6.31-37

Srivastava, S., & Garg, R. K. (2017a). Process parameter optimization of gas metal arc welding on IS : 2062 mild steel using response surface methodology. Journal of Manufacturing Processes, 25, 296–305. https://doi.org/10.1016/j.jmapro.2016.12.016

Srivastava, S., & Garg, R. K. (2017b). Process parameter optimization of gas metal arc welding on IS : 2062 mild steel using response surface methodology. Journal of Manufacturing Processes, 25, 296–305. https://doi.org/10.1016/j.jmapro.2016.12.016

Vedrtnam, A., Singh, G., & Kumar, A. (2018). Optimizing submerged arc welding using response surface methodology, regression analysis, and genetic algorithm. Defence Technology, 14(3), 204–212. https://doi.org/10.1016/j.dt.2018.01.008

Wordofa, T. N., Perumalla, J. R., & Sharma, A. (2024). An artificial intelligence system for quality level–based prediction of welding parameters for robotic gas metal arc welding. The International Journal of Advanced Manufacturing Technology, 132(7–8), 3193–3212. https://doi.org/10.1007/s00170-024-13518-7

Zamzami, I. Al, Davison, J. B., & Susmel, L. (2017). Static Strength of aluminium-to-steel thin welded joints: Preliminary results. BSSM 12th International Conference on Advances in Experimental Mechanics, 3–4.