

Optimization of Robotic GMAW Parameters for Enhanced Quality of 3G Mild Steel Welds

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Abstract

With the increasing adoption of robotic welding systems in industrial manufacturing, understanding the precise control of welding parameters in this difficult position has become essential to ensuring consistent welding quality. This study focuses on evaluating the effects of key Robotic Gas Metal Arc Welding (GMAW) parameters namely current, voltage, and wire feed rate on weld bead appearance, root penetration, and tensile strength when applied to mild steel plates. The research aims to identify the optimal parameter combination capable of maximizing weld quality while minimizing defects, enabling more reliable robotic welding performance in the 3G position. To achieve this, the Taguchi Method was employed to design a robust and systematic experimental framework, allowing efficient parameter variation and analysis. An ABB IRB 1520ID robotic arm integrated with a Fronius TPS 320i robotic GMAW machine was used to ensure repeatability and control throughout the welding trials. A total of nine experimental specimens were produced based on an L_9 orthogonal array, with each specimen subjected to visual non-destructive testing (NDT) to assess surface discontinuities and destructive testing (DT) to determine mechanical integrity. Analysis of the experimental data revealed that welding current, voltage, and wire feed rate significantly influence weld penetration and strength in the 3G position. The study identified 110 A of current, 17.9 V of voltage, and a wire feed rate of 2.7 m/min as the optimum parameter settings, achieving a superior tensile strength of 403 N/mm² and eliminating root penetration defects. Furthermore, optimal visual quality was quantified at 80 A, which yielded a 100% defect-free weld bead and root pass. Overall, the findings demonstrate that by establishing an optimized parameter window, this research contributes to improved process reliability, enhanced weld quality, and greater industrial applicability.

Keywords: *gas metal arc welding; non-destructive testing; root penetration; robotics welding; welding parameters.*

Introduction

The traditional fusion arc welding techniques such as Gas Metal Arc Welding (GMAW) and Shielded Metal Arc Welding (SMAW) are extensively employed to join such structural steels (Salvador, 2023). These welding methods remain highly popular because they enable effective melting and fusion of the base steel, providing a reliable and versatile means of fabricating load-bearing and high-strength structures under a variety of industrial conditions. In new area, fully automated welding robots have become common in manufacturing. Automating the welding process which in turn elevates the performance and efficiency of robotic welding systems (Dias et al., 2023).

Automated welding technologies ensure a reliable and repeatable welding operation, promoting uniform weld quality and reducing the probability of defects. By utilizing robotic automation, manufacturers gain precise control over welding parameters, leading to improved weld-bead geometry, consistent penetration, and overall superior weld integrity (Bhattacharjee & Roy, 2025; Guillo & Dubourg, 2016; Zheng et al., 2022). Moreover, employing robotic systems in welding operations enables companies to ramp up production rates, cut operating costs, and consistently deliver dependable weld quality. When advanced Gas Metal Arc Welding (GMAW) techniques are combined with robotic platforms, there is considerable potential for welding various non-ferrous metals and achieving high-quality joints across different material grades. In the welding business, this technique is becoming increasingly common, especially with the quick development of automation (Cao & Zhang, 2025; Li et al., 2023; Lu et al., 2014; Yu et al., 2024; Yuan et al., 2019). Because of its inability to keep up with changing industrial needs, traditional welding techniques like direct-current (DC)

welding at constant voltage have given way to GMAW, which is especially useful in robotic welding systems (Bu et al., 2024).

The robotic GMAW techniques are widely used in a variety of industrial applications because they provide the advantages of regulated heat input, all position welding capabilities and less spatter generation (Moinuddin et al., 2024). On top of that, it has been noted that the use of GMAW in Wire Arc Additive Manufacturing (WAAM) is a viable alternative for effectively creating large volumes of metal parts (Henckell et al., 2020). To precisely regulate the welding parameters and the deposition of welded material, an electric arc is created between the workpiece and a consumable wire electrode (Mollayi & Eidi, 2018). The 3G welding position is a highly demanding vertical groove weld where workpieces are fixed upright at a 90-degree angle, requiring the weld progression to be executed either vertically upward or downward (Rout et al., 2020). The primary challenge in this orientation is gravity, which constantly pulls on the molten metal pool, making the weld highly susceptible to defects such as sagging, lack of root penetration, and uneven fusion. Implementing robotic welding automation for 3G applications is critical because it enables exact, repeatable control over crucial operating parameters like current, voltage, and wire feed rate (Peng et al., 2024). By explicitly optimizing these robotic parameters, manufacturers can strictly regulate the heat input, arc stability, and weld termination sequences, successfully counteracting the gravitational pull to prevent common flaws like "poor stops" or underfill, ultimately producing robust joints with maximized tensile strength and superior structural reliability (Shojaee et al., 2021).

Mild steel has advantages in the welding sector because of its advantageous qualities and adaptability. Since mild steel is inexpensive, easy to work with and has great mechanical strength, it is a favorite material for welding industry. One important benefit of mild steel is its simplicity of manufacture, which makes it appropriate for a variety of welding applications across multiple industries (Liu et al., 2003; Nukathoti et al., 2024; Patil et al., 2023; Saleh et al., 2023). In addition, due to its adaptability, according to (Olgun et al., 2020), mild steel can be used in a variety of welding procedures, including Shielded Metal Arc Welding (SMAW) and Gas Metal Arc Welding (GMAW). These welding techniques are widely utilized because they are economical, efficient and adaptable to automation for joining mild steel. In addition to those benefits, mild steel resistance spot welding (RSW) offers cheap cost, high production efficiency and automation flexibility, making it an excellent choice for large-scale manufacturing (Pasau et al., 2024). Furthermore, the substantial residual stress and workpiece distortion that might arise from the high-power input required to weld mild steel can impair the overall quality of the weld. The welding process is further complicated by mild steel's propensity to fracture in the heat affected zone (HAZ) and weld (Węgrzyn et al., 2021).

In this investigation, structured experiments will be designed to examine how individual welding parameters influence weld- bead characteristics, root penetration, and tensile strength in 3G welding position. Subsequently, once data are collected, an in-depth analysis and interpretation will be performed to elucidate the relationships between parameter settings and weld outcomes enabling the determination of optimal parameters for high-quality 3G-position welds. In effective welding quality control, visual inspection is one of the basic forms of evaluation of weld results. In basic control evaluation, reference to the evaluation of weld results is in the form of standards or codes that are used as criteria for evaluating weld results to be accepted or rejected.

Materials and Methods

In this research, the dimensions of the mild steel plates are 120 x 100 x 9 mm. A single "V" notch with a 45-degree angle was prepared for the weld trials. Explicitly state that mild steel was selected because of its widespread use in load-bearing structures across the manufacturing, transportation, and construction sectors. Explain that ER70S-6 filler wire and 100% CO₂ with constant flow rate of 15 L/min shielding gas were selected because they are the industry standard combination for producing deep penetration and high-strength joints in mild steel and its cost-effectiveness in industrial mild steel applications.

The experimental setup for the GMAW processes included the primary welding equipment and its associated accessories. In order to carry out the welding experiment, the electrode used was ER70S-6 for GMAW with wire diameter 1.2 mm. ER70S-6 filler wire has relatively high content of deoxidizing elements, which enables it to function effectively as a strong deoxidizer. This characteristic is particularly important when using 100% CO₂ shielding gas, where enhanced deoxidation is required to maintain weld quality. The chemical compositions and mechanical characteristics of the base metal and electrodes are presented in Tables 1 and Table 2 respectively. To systematically evaluate the robotic GMAW process, the experimental parameters were divided into constant and variable categories. Fixed parameters including the shielding gas (CO₂), filler wire diameter (1.2 mm), and groove angle (45) were strictly held constant. Keeping these elements constant was essential to isolate the experiment's variables and prevent data

confounding variables. If these fixed factors were varied simultaneously, it would be impossible to accurately attribute changes in weld quality to a specific cause.

Table 1 Constant Parameter

Constant Parameters	Value/Type
Gas	100% CO ₂
Gas Flow Rate	15 L/min
Filler Wire Size (mm)	1.2mm
Filler Wire Type	ER70S-6
Groove Angle	45°

Table 2 Chemical Composition of Mild Steel

Element	Typical Composition (%)	Function / Notes
Carbon (C)	0.05 – 0.25%	Controls hardness and strength; low carbon improves ductility and weldability.
Manganese (Mn)	0.25 – 0.90%	Increases toughness and strength; helps remove oxygen during steelmaking.
Silicon (Si)	0.10 – 0.40%	Improves strength and acts as a deoxidizer.
Sulfur (S)	≤ 0.05%	Impurity; excess reduces ductility and weldability.
Phosphorus (P)	≤ 0.04%	Impurity; increases brittleness if too high.
Iron (Fe)	Balance	Base metal forming the majority of mild steel.

Experimental Setup

For the trial, the GMAW robotic welding process used to evaluate weld-bead quality, root-penetration performance, and tensile strength was carried out using the FRONIUS TPS 320i welding machine, as illustrated in Figure 1. The welding operations were further supported by an ABB robotic welding system, specifically the IRB1520ID model. The specifications of the FRONIUS TPS 320i and the ABB IRB1520ID are presented in Tables 3 and 4, respectively. The use of a robotic system is justified because the 3G vertical welding position is highly affected by gravity and demands precise, repeatable control of heat input, which manual welding cannot consistently achieve. The ABB robotic arm combined with the Fronius welding machine was therefore selected to minimize human error and ensure strict adherence to the programmed parameters across all specimens.



Figure 1 FRONIUS TPS 320i and robotic arm ABB IRB1520ID.

Table 3 Specifications of FRONIUS TPS 320i

Main Voltage	3x 400V, 50/60Hz
Main Fuse Protection	35A slow-blow
Main Voltage Tolerance	+/- 15%
Cos phi	0.99
Welding Amps Range	3-320 Amps
Welding Current at 10min/40°C	40% 320A / 60% 260A / 100% 240A
Open Circuit Voltage	14.2 – 34.0V
IEC Ingress Protection Rating	P 23
Dimension (L x W x H)	706 x 300 x 510mm
Weight	35.8 kg

Table 4 Specification of Robotic Arm ABB IRB 1520ID Specifications.

No. of Axes	6 Axis
Payload	4 kg
Arm Load	10 kg
Reach at Wrist	Drive Module, Single Cabinet 0.05mm
Position Repeatability (RP)	0.35mm
Path Repeatability (RT)	6 Axis

Table 5 Control factors and their corresponding experimental levels for the 3G robotic GMAW process

Symbols	Control Factors	Unit	Level 1	Level 2	Level 3
1	Welding Current	A	60	100	140
2	Arc Voltage	V	16.8	17.7	19.3
3	Wire Feed Rate	m/min	1.7	2.5	4.0

Table 6 Taguchi L₉ orthogonal array design matrix for the welding trials.

Specimen No.	Amperage (A)	Voltage (V)	Wire Feed Rate (m/min)
1	60	16.8	1.7
2	60	17.7	2.5
3	60	19.3	4.0
4	100	16.8	1.7
5	100	17.7	2.5
6	100	19.3	4.0
7	140	16.8	1.7
8	140	17.7	2.5
9	140	19.3	4.0

Based on Table 5 control factors and their corresponding experimental levels for the 3G robotic GMAW process and Table 6 Taguchi L₉ orthogonal array design matrix for the welding trials, the chosen input factors for this study are, three variables which is current (A), voltage (V) and wire feed rate (m/min) were chosen. The parameters used in this research were controlled using the FRONIUS Model: TPS 320i standard. All of the samples were welded by GMAW process to build V-grooved butt joints, with the electrode being positioned at the optimal distance above the joint throughout the operation. Welding parameters were maintained in the following manner throughout all of the experiments. The Taguchi method was selected as a systematic framework to efficiently evaluate multiple variables while minimizing the number of experimental runs. In addition, Visual Testing (VT) and Destructive Tensile Testing (DT) were employed together to provide a comprehensive assessment of both surface integrity and internal mechanical strength (Abhishek et al., 2024; Bandhu, 2026; Yadav et al., 2024)

Results

Workpieces for the visual testing (ASTM E165) and tensile strength are prepared as per ASTM E8/E8M standards. The yield tensile strength (YTS), ultimate tensile strength (UTS) and process parameters are compiled in Table 4. In Figure 2 to Figure 10 represent the visual testing result. A visual inspection form is a structured checklist used in welding research to systematically document observations from visual testing (VT) of welded joints.

Visual Testing for Weld Bead and Root Penetration

Visual Testing (VT) was conducted on all nine welded specimens to evaluate weld bead appearance and root penetration quality, focusing on visible defects such as undercut, lack of fusion, crater defects, excessive reinforcement, porosity, and irregular penetration. The visual inspection results for the nine specimens are as follows:

1. Specimen 1: This specimen showed an acceptable weld bead but exhibited a lack of penetration on the root side, placing it as out of tolerance, although a defect-free area was still available for extracting the tensile coupon.
2. Specimen 2: This sample presented a crater defect on the weld bead and lack of penetration at the root. Both were classified as out of tolerance, yet a compliant section remained for tensile testing.
3. Specimen 3: This was the only sample with a fully defect-free weld bead and root penetration and was therefore accepted.
4. Specimen 4: This specimen displayed a crater defect on the weld bead but had an acceptable root.
5. Specimen 5: This specimen had an acceptable bead but a crater defect at the root.

6. Specimen 6: This specimen showed a crater defect on the weld bead but no defects in the root penetration.
7. Specimen 7: This sample exhibited multiple severe defects, including excessive reinforcement, undercut on the bead, and underfill at the root, all of which were considered as rejectable.
8. Specimen 8: This specimen also presented major bead defects, such as undercut and lack of fusion, as well as an underfill defect at the root.
9. Specimen 9: This sample showed a lack of fusion and a crater defect on the bead, along with underfill on the root. This placed both evaluations as out of tolerance.

For all specimens, even when defects were present, a defect-free zone (indicated by the yellow rectangle in each figure) was identified to allow proper extraction of tensile test coupons.



Figure 2 Specimen 1 weld bead and root pass.



Figure 3 Specimen 2 weld bead and root pass.



Figure 4 Specimen 3 weld bead and root pass.



Figure 5 Specimen 4 weld bead and root pass.



Figure 6 Specimen 5 weld bead and root pass.



Figure 7 Specimen 6 weld bead and root pass.

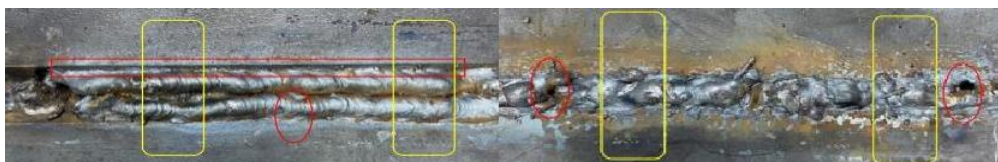


Figure 8 Specimen 7 weld bead and root pass.

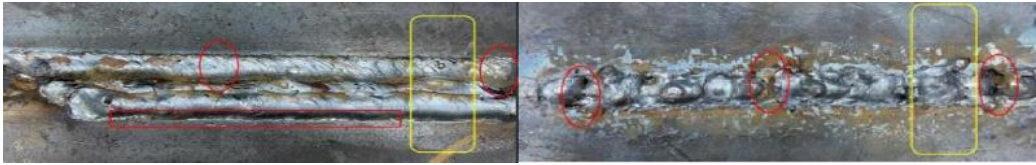


Figure 9 Specimen 8 weld bead and root pass.



Figure 10 Specimen 9 weld bead and root pass.

The visual inspection results show in Table 7 a clear trend in weld quality across the different parameter settings. The best overall weld quality was observed in Specimen 3 (80 A, 17.3 V, 2.0 m/min), which produced a defect-free weld bead and root penetration, indicating that a moderate heat input provides the most balanced melting and fusion. At lower parameters, such as in Specimens 1 and 2 (60–70 A), the weld bead was acceptable, but both samples showed lack of penetration, confirming that insufficient current does not generate enough heat to fully fuse the joint. As the current increased to the mid-range values (90–110 A in Specimens 4–6), weld bead quality became inconsistent, with recurring poor stop defects, while root penetration alternated between acceptable and poor, suggesting instability in arc control or excessive travel speed. At high parameter settings (120–140 A in Specimens 7–9), the weld quality deteriorated significantly, with multiple serious defects including excessive reinforcement, undercut, lack of fusion, underfill, and poor stop, indicating that excessive current and wire feed rate introduce too much heat and deposition, resulting in unstable metal transfer and weak joint formation. Overall, the data show that low parameters cause insufficient penetration, high parameters cause multiple bead and root defects due to overheating, and the optimal welding condition lies around 80 A with moderate voltage and wire feed rate, which produced the only fully defect-free welding

Table 7 Specimen’s Defects

Specimen	Current (A)	Voltage (V)	Wire Feed Rate (m/min)	Weld Bead Defects	Root Defects / Penetration
1	60	16.8	1.7	No Flaws	Lack of Penetration
2	60	17.7	2.5	Poor Stop	Lack of Penetration
3	60	19.3	4.0	No Flaws	No Flaws
4	100	16.8	1.7	Poor Stop	No Flaws
5	100	17.7	2.5	No Flaws	Poor Stop
6	100	19.3	4.0	Poor Stop	No Flaws
7	140	16.8	1.7	1. Excessive Face Reinforcement (3mm) 2. Undercut	Lack of Fusion
8	140	17.7	2.5	Undercut	Lack of Fusion
9	140	19.3	4.0	Poor Stop	Underfill

Tensile Testing

Tensile testing was carried out in accordance with ASTM E8/E8M, the standard procedure for evaluating the tensile properties of metallic materials. The tests were performed using a calibrated tensile testing machine compliant with all relevant industry specifications. This evaluation aimed to determine the mechanical performance of the welded joints, particularly focusing on their tensile strength, load-carrying capacity, and overall structural integrity under uniaxial stress as shown in Figure 11.

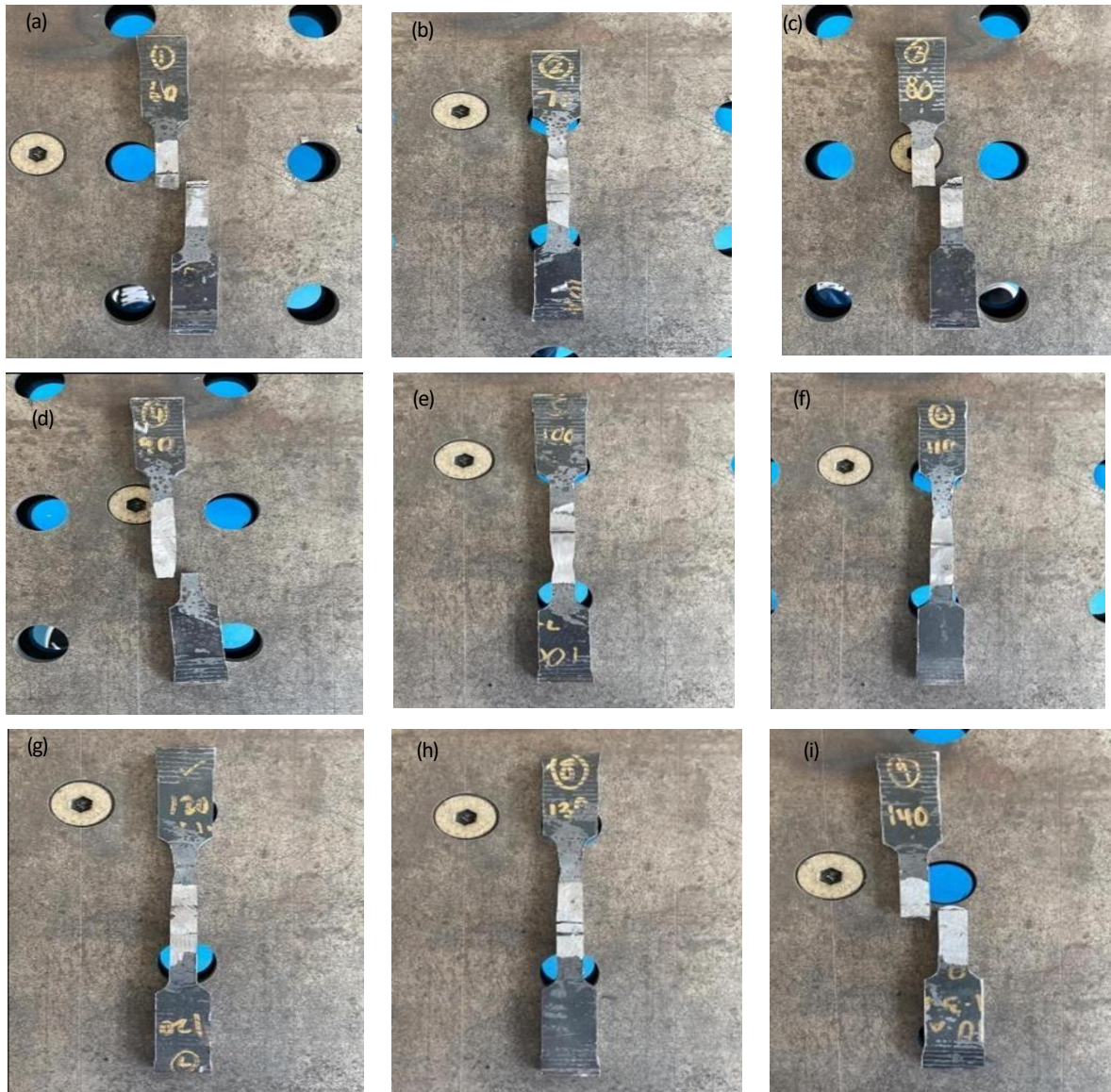


Figure 11 Sample after Tensile Test.

The tensile test results show in Table 8 that weld quality improves progressively as yield load, yield strength, ultimate load, and tensile strength increase, with optimal performance occurring in the mid-to-high parameter range. Specimens 6, 7, and 8 exhibit the best mechanical properties, achieving high yield strength values (296–319 N/mm²), high tensile strengths (403–417 N/mm²), and good elongation (33–34%), demonstrating a strong balance between strength and ductility. These results suggest that the corresponding welding parameters produced sound fusion and adequate heat input, resulting in a robust joint. Specimens 2, 4, and 5 also demonstrate acceptable quality, with moderate-to-high strength values (i.e., yield strength 273–287 N/mm² and tensile strength 387–399 N/mm²) and elongation (36–40%), evidencing good ductility and stable weld formation. In contrast, specimens 1 and 3 show lower-quality welds, with reduced yield and tensile strengths (yield strength 251–269 N/mm²; tensile strength 322–380 N/mm²) and lower elongation (24–27%), pointing to insufficient heat input or incomplete fusion. The poorest performance is seen in Specimen 9, which records the lowest strength (yield strength 246 N/mm²; tensile strength 311 N/mm²) and the lowest elongation (22.67%), suggesting weak bonding, potential defects, or inadequate penetration. Overall, the data confirms that medium-high parameters yield the strongest and most ductile welds, while too low heat input results in reduced strength and poor mechanical performance (Doredla & N, 2025).

The regression analysis indicates in Figure 12, a slight negative trend in both tensile strength and S/N ratio; however, the presence of a peak at Specimen 7 suggests that the process behavior is non-linear. The highest S/N ratio (52.40 dB) confirms that Specimen 7 represents the optimal and most robust parameter combination. Therefore, Taguchi analysis provides a more reliable method for optimization compared to linear regression.

Table 8 Experimental Results for Tensile Strength, Standard Deviation, and S/N Ratio Specimen

Specimen	Test 1 (N/mm ²)	Test 2 (N/mm ²)	Test 3 (N/mm ²)	Mean Tensile Strength (N/mm ²)	Standard Deviation (SD)	S/N Ratio (dB)
1	378	383	379	380	2.65	51.60
2	402	397	398	399	2.65	52.02
3	320	325	321	322	2.65	50.16
4	394	399	395	396	2.65	51.95
5	385	390	386	387	2.65	51.75
6	405	401	403	403	2.00	52.11
7	415	420	416	417	2.65	52.40
8	410	405	406	407	2.65	52.12
9	313	309	311	311	2.00	49.86

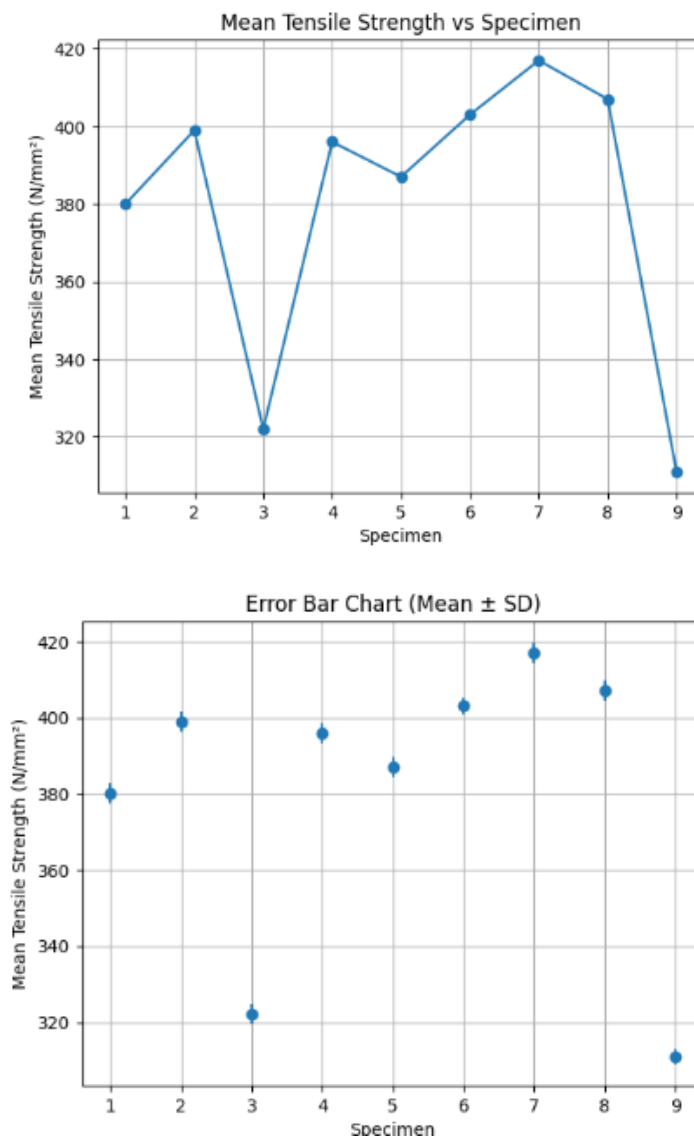


Figure 12 Result of Tensile Test

Discussion

Common weld bead flaws include undercut, a groove at the weld edge that reduces material strength; excessive face reinforcement (>3 mm); and poor stops, which indicate inconsistent weld termination. These defects typically stem from inappropriate electrode movement and insufficient control over heat input (Ghofrani et al., 2014). Consequently, rigorous inspection methods, such as radiography and advanced image processing, are essential for categorizing these defects (Jin et al., 2021). Specific to root penetration, defects such as underfill (surface below the required level), lack

of penetration (insufficient base metal fusion), and lack of fusion are frequently observed. To mitigate these issues, technological advancements such as machine vision systems and closed-loop control mechanisms are increasingly applied to regulate penetration (Kalyankar & Naik, 2021).

In this study, weld quality and mechanical performance varied significantly across specimens due to fluctuations in current, voltage, and wire feed rate shown in Table 8. The mean tensile strength plot reveals a non-linear trend, with a pronounced peak at Specimen 7 (417 N/mm²), followed by a sharp decline at Specimen 9 (311 N/mm²). This indicates that increasing heat input does not consistently improve weld performance but instead leads to instability beyond optimal conditions. The error bar analysis (mean $\pm$ SD) shows relatively consistent variability across specimens, although Specimens 6 and 9 exhibit slightly lower standard deviation, indicating more stable process conditions. However, stability alone does not guarantee optimal weld quality, as evidenced by the poor mechanical performance of Specimen 9.

The S/N ratio analysis illustrated in Figure 12, based on the Taguchi method, further clarifies process robustness. Specimen 7 recorded the highest S/N ratio (52.40 dB), indicating the best combination of strength and robustness, whereas Specimen 9 showed the lowest value, confirming poor reliability. Although Specimen 7 demonstrates superior mechanical strength, visual inspection revealed the presence of root defects such as underfill and lack of fusion, likely due to excessive heat input. This highlights a critical trade-off between maximizing strength and maintaining weld integrity.

Defect distribution across specimens supports this observation. Underfill and lack of fusion were more prevalent at higher heat input conditions (Specimens 7, 8, and 9), while lack of penetration was observed at lower parameter settings (Specimens 1 and 2). Recurring “poor stop” defects across multiple specimens suggest inconsistencies in weld termination. To address this issue, the robotic programming parameters governing the arc termination sequence—namely crater fill duration, burn back voltage/time, and end-of-weld dwell time—must be systematically optimised. Proper calibration of these parameters ensures consistent crater filling and prevents premature arc extinguishment, thereby eliminating termination-related defects.

The mechanical performance evaluation confirms that while Specimen 7 achieved the highest tensile strength, it does not represent the most reliable condition due to defect formation. Conversely, Specimen 9 exhibited the lowest tensile strength and elongation, indicating reduced ductility and a higher susceptibility to brittle failure. Specimens 3 and 9 showed characteristics of brittle fracture, whereas Specimens 2, 4, and 6 demonstrated better ductility and energy absorption capacity.

Considering both mechanical performance and process stability, Specimen 6 provides the most balanced and reliable parameter combination. With a tensile strength of 403 N/mm² and relatively low variability, it offers a stable, defect-minimized condition compared to higher heat-input specimens. Although its S/N ratio is slightly lower than that of Specimen 7, the absence of critical defects makes it more suitable for practical applications. Therefore, the results indicate that optimal welding parameters should prioritize a balance among strength, consistency, and defect minimization, rather than maximizing tensile strength alone.

Conclusions

This study systematically investigated the optimization of robotic Gas Metal Arc Welding (GMAW) parameters to improve the quality of mild steel joints in the 3G vertical position. Using an automated ABB robotic system and a Taguchi L9 orthogonal array, the effects of current, voltage, and wire feed rate on weld integrity and mechanical performance were evaluated through tensile testing and defect analysis.

The graphical analysis provides important insights into process behaviour, revealing a non-linear correlation between heat input and tensile strength, with a peak at Specimen 7 (417 N/mm²) followed by a significant drop at Specimen 9. The error bar analysis (mean $\pm$ SD) demonstrates relatively consistent variability across most specimens. Notably, while Specimen 9 achieved high process repeatability (lower variability), its mechanical reliability ultimately failed due to the adverse effects of excessive heat. Furthermore, the S/N ratio analysis highlights Specimen 7 as having the highest robustness (52.40 dB), while Specimen 9 exhibits the lowest reliability, reinforcing the presence of suboptimal welding conditions at extreme parameter settings.

The results confirm that excessive heat input (Specimens 7–9) can increase tensile strength but simultaneously promotes weld defects such as underfill, excessive reinforcement, and lack of fusion. In contrast, insufficient heat input (Specimens 1–2) leads to inadequate penetration and reduced joint strength. These findings demonstrate that weld quality in the 3G position is governed by an optimal process window, rather than a simple linear relationship. Based on the combined evaluation, Specimen 6 represents the most balanced and reliable parameter set. Although it does not achieve the absolute maximum tensile strength, it provides a high strength of 403 N/mm² with lower variability and

minimal defect formation. This confirms that optimal welding performance should prioritize a balance between mechanical properties and defect minimization rather than maximizing strength alone.

The study limitations include the use of a single mild steel thickness, a limited range of welding parameters, and an evaluation restricted to visual inspection and tensile testing. Overall, this study establishes a clear and practical parameter window for robotic 3G GMAW of 9 mm mild steel, contributing to improved process reliability and joint quality in industrial applications. Future work should extend this optimization to different material thicknesses and incorporate real-time, closed-loop control systems to further enhance weld consistency and eliminate surface and root defects

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Compliance with ethics guidelines

The authors declare they have no conflict of interest or financial conflicts to disclose.

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