Journal of Welding Technology
P-ISSN: 2716-1471 | E-ISSN: 2716-0475
http://e-jurnal.pnl.ac.id/Welding_Technology

Analysis of weld defects and corrosion rates in SS304–SS400 dissimilar joints under various MIG welding positions

Yoggo Bagus Pamungkas*, Nani Mulyaningsih, Sri Hastuti, R.Faiz Listyanda
Department of Mechanical Engineering, Faculty of Engineering, Tidar University, Jl. Kapten Suparman 39, Magelang City, Central Java, Indonesia Corresponding author: E-mail: baguszogga@gmail.com

Article Processing Dates:
Received 2026-02-08
Accepted 2026-06-01
Available online 2026-06-30

Keywords:
SS400 Carbon Steel, MIG Welding Defects, Corrosion, Welding Position, SS304 Stainless Steel

Abstrak

The combination of SS304 stainless steel and SS400 low-carbon steel is widely used in the automotive and construction sectors because it combines weldability with good corrosion resistance. However, the differences in the physical and mechanical properties of these two materials have the potential to affect the quality of the welded joint, especially when considering variations in welding position. This study aims to analyze the effect of 1G, 2G, and 3G welding positions on welding defects and the corrosion rate of Metal Inert Gas (MIG) welded joints. The materials used were SS304 stainless steel plates and SS400 lowcarbon steel plates joined using a 60° V-groove. The welding process was performed using a current of 70 A as the primary parameter and ER309L electrode wire for all welding position variations. Welding defect testing was performed using the liquid penetrant method in accordance with ASTM E165 to detect surface defects, and corrosion rate testing was conducted using the electrochemical method in a NaCl solution, referencing ASTM G102 to determine the corrosion resistance of the welded joints. The test results showed that the 1G welding position produced the fewest welding defects compared to the 2G and 3G positions, and the 1G welding position yielded the lowest corrosion rate of 0.0789 mmpy, while the 2G and 3G positions showed corrosion rates of 0.1301 mmpy and 0.1699 mmpy, respectively. These values indicate that welded joints in the 1G position have better corrosion resistance compared to other positions. This difference is influenced by the stability of the weld pool, the effect of gravity, and the lower likelihood of weld defects in the 1G position. Thus, the welding position plays a crucial role in determining the quality and corrosion resistance of MIG weld joints in dissimilar materials, specifically SS304 stainless steel and carbon steel. SS400 low-carbon steel.

1. Introduction

A towing bar is a critical component of motor vehicles that functions as a device for towing loads, such as trailers or other vehicles. During operation, the towing bar is subjected to significant tensile, compressive, and torsional loads, thus requiring high mechanical strength and environmental resistance [1]. One of the main issues with towing bars is damage caused by corrosion, as these components are typically mounted on the exterior of the vehicle and exposed to rain, humidity, and the environment [2]. Corrosion can reduce strength and accelerate component failure, impacting the safety and service life of the towing bar.

Stainless Stainless steel 304 is known for its good corrosion resistance due to its high chromium and nickel content [3], while low-carbon steel SS400 is easy to weld, ductile, and more economical [4]. Combining these two materials through welding is expected to produce joints with minimal welding defects and better corrosion resistance [5].Metode pengelasan Metal Inert Gas (MIG) dipilih karena mampu menghasilkan sambungan yang rapi, penetrasi baik, dan minim cacat [6].

However, differences in material properties and variations in welding positions can affect the quality of the welded joint [7]. Therefore, this study aims to evaluate the effect of 1G, 2G, and 3G welding positions on welding defects and the corrosion rate of MIG welded joints between SS304 stainless steel and SS400 low-carbon steel using a 60° V-groove and 70 amps as the main parameters for all welding position variations [8]. The results of this study are expected to serve as a basis for the development of stronger, corrosion-resistant, and safer towing bar

2. Research Methodology

This study was conducted at the Tidar University laboratory using an experimental approach, specifically by performing the welding process directly and testing the weld joints to examine the effect of variations in welding position (1G, 2G, 3G) on welding defects and corrosion resistance. The materials used in this study were SS304 stainless steel with dimensions of 100 mm x 100 mm and SS400 low-carbon steel with dimensions of 100 mm x 100 mm and a plate thickness of 3 mm, consisting of 6 plate sections as the base material for welding. The joining process was performed using Metal Inert Gas (MIG) welding. The main equipment used included a MIG welding machine, welding wire, shielding gas, as well as other supporting equipment for the welding and testing processes. The 304 stainless steel and SS 400 low carbon steel materials can be seen in Fig.s 1 and 2.

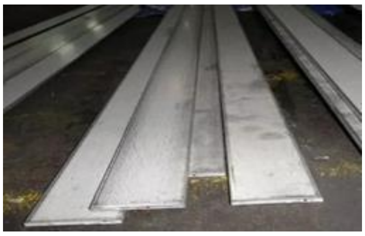

Fig. 1. 304 Stainless Steel Material

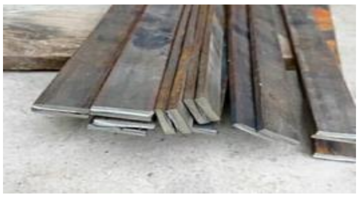

Fig. 2. Low-carbon steel SS400 material The

Reation of a 60° V-groove is performed using a grinder with a bevel to determine a 30° angle on each material. This process aims to form a V-shaped groove so that the total groove angle reaches 60° [9]. The groove preparation is carried out carefully to ensure the groove angles are uniform and in accordance with the specified requirements, as shown in Fig. 3.

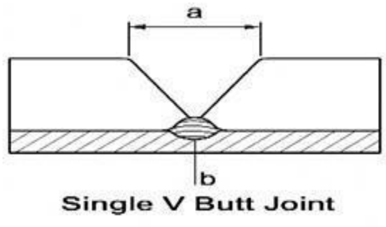

Fig. 3. 60° V-groove

Welding is performed in the 1G, 2G, and 3G positions, each of which has a different welding orientation [10]. These differences affect the flow of molten metal, the formation of the weld bead, and the quality of the resulting weld joint. These variations in welding position are used to determine the effect of position on the characteristics of the weld. See Fig. 4.

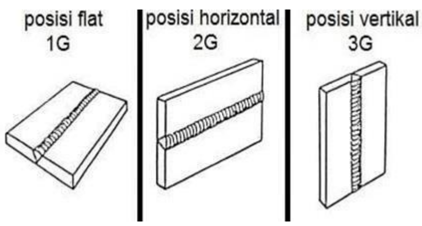

Fig. 4. Welding Positions

Welding was performed using a 70-amp current for each variation, as 3-mm-thick plates were used; the resulting weld joints were successfully formed without distortion across all 1G, 2G, and 3G welding positions [11]. These were subsequently used as specimens for weld defect testing in accordance with the ASTM E165 standard. See Fig. 5.

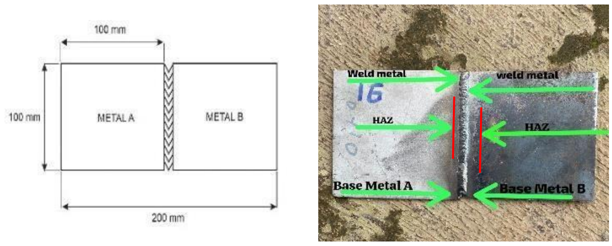

Fig. 5. Welding defect test specimens

Corrosion test specimens for the 1G, 2G, and 3G welding positions, which were subsequently used in the corrosion rate testing process, can be seen in Fig. 6.

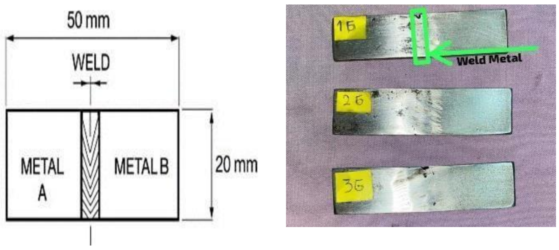

Fig. 6. Corrosion test specimens

Welding defect testing was performed using the liquid penetrant method based on the ASTM E165 standard to identify welding defects in each welding position variation. See Fig. 7.

Fig. 7. *Liquid penetrant*

Corrosion testing was performed using the electrochemical method based on the ASTM G102 standard to determine the corrosion rate for each welding position variation and to calculate the Equivalent Weight (EW) and Icorr values using the Icorr test software [12]. See Fig. 8.

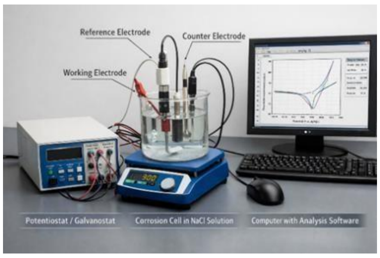

Fig. 8. Potensiostat

3. Results and Discussion

3.1. Results of Weld Defect Testing

Welding defect testing is conducted during the welding process. Welding defects prior to flattening are those occurring on the surface of the weld bead (Table 1), whereas welding defects after flattening are those located within the weld metal or the joint area that are not visible to the naked eye. Results of 1G weld defect testing before and after leveling shows in Fig. 9-11.

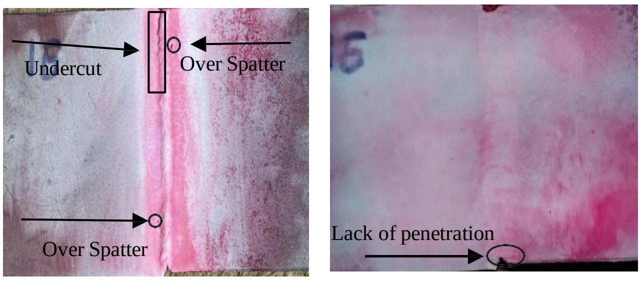

Fig. 9. Results of 1G weld defect testing before and after leveling

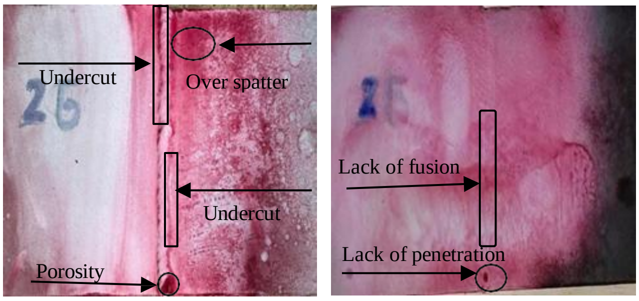

Fig. 10. Results of 2G weld defect testing before and after leveling

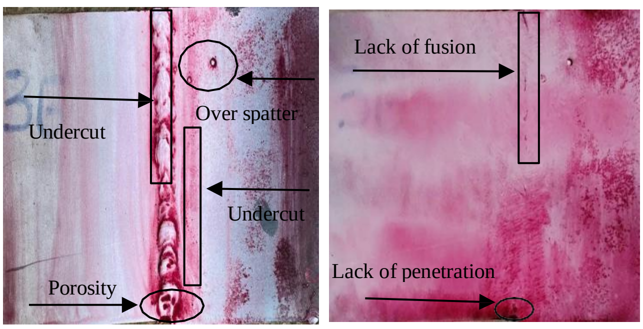

Fig. 11. Results of 3G weld defect testing before and after leveling

Table 1. Welding defect results

Variations in welding position	Welding defects before leveling	Welding defects after leveling
1G	*Undercut*	*Lack of penetrantion*
	Over spatter	-
2G	*undercut*	*Lack of penetrantion*
	Over spatter	*Lack of fusion*
	Porosity	-
3G	*Undercut*	*Lack of penetration*
	Over spatter	*Lack of fusion*
	Porosity	-

The data in Table 1 above shows that position 1G exhibits welding defects such as undercut, overspray, and lack of penetration [13]. These three defects occur due to excessive welding speed, an improper electrode angle, and too slow an electrode swing; however, the stable shielding gas flow and position result in the 1G position having very few defects and excellent weld quality, so that the welding position below the hand has excellent gravitational balance and presents no difficulty [14]. The 2G position exhibited undercut defects and slight porosity caused by welding speed and uneven heat distribution. Meanwhile, the 3G position showed lack of fusion due to difficulties in controlling the weld pool in the vertical position and the effect of gravity on the flow of molten metal [15].

3.2. Corrosion Test Results

Corrosion rate testing was conducted to evaluate the corrosion resistance of dissimilar GMAW/MIG welded joints between SS304 stainless steel and SS400 low-carbon steel plates with a thickness of 3 mm. The electrochemical measurements were performed at the Casting and Welding Laboratory, Faculty of Engineering, Universitas Sebelas Maret, Indonesia. Corrosion behavior was evaluated using the potentiodynamic polarization technique with a potentiostat. The corrosion current density (I_{corr}) was determined using the I_{corr} analysis software, while the equivalent weight (EW) of SS304 stainless steel was taken as 27.008. The corrosion rate (CR) was then calculated according to Equation (1):

$$\textit{Corrosion rate}\ (CR) = K \times \frac{EW \times Icorr}{\rho} \quad \text{.............................}(1)$$

Notes:

CR = Corrosion (mm/year or mmpy)

K = Konstanta (0,00327 to mmpy)

EW = Equivalent weight (g)

ρ = Metal density (7,874 gram/cm³)

Icorr = Current density (μA/cm²)

The calculation of corrosion rate as in Table 2.

Table 2. Corrosion Rate Calculation

Variations in welding position	I_{corr} (μA/cm²)	CR (mmpy)	Corrosin resistane category
1G	7,013	0,0789	*Excellent*
2G	11,609	0,1301	*Good*
3G	15,155	0,1699	*Good*

The results in Table 2 of the corrosion rate test calculations show that the welding position affects the corrosion rate of SS304 stainless steel and SS400 low carbon steel weld joints, where the 1G position variation has a corrosion rate of 0.0789 mmpy. The 2G position variation has a corrosion rate of 0.1301 mm/year, while the 3G position variation has a corrosion rate of 0.1669 mm/year.

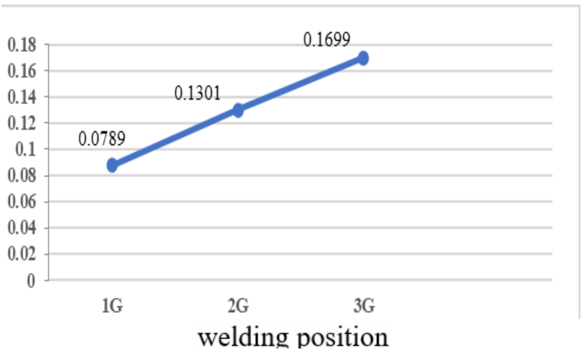

Fig. 12. Corrosion Rate Graph

Fig. 12 show the welding position variations 1G, 2G, and 3G significantly affect the quality of the dissimilar weld joint between SS304 stainless steel and low carbon steel SS400 welded using the MIG method. The 1G welding position produces the lowest corrosion rate of 0.0789 mmpy due to minimal welding defects and more uniform metal fusion. This difference in corrosion rate is influenced by weld pool stability, the effect of gravity, welding defects, and welding parameters that determine the physical quality and mechanical strength of the joint [16].

4. Conclusion

The research results show that in welding defect testing, the 1G welding position produces the best weld bead quality Compared to the 2G and 3G positions. This is indicated by the relatively fewer types and levels of defects, which are also easier to control, as the flat welding position provides better weld pool stability and heat distribution. Variations in welding positions significantly affect the corrosion rate of dissimilar stainless steel SS304 and low-carbon steel SS400 weld joints welded using the Metal Inert Gas (MIG) method [17]. The 1G welding position yields the lowest corrosion rate of 0.0789 mmpy with an "excellent" corrosion resistance rating, while the 2G and 3G positions exhibit higher corrosion rates of 0.1301 mmpy and 0.1699 mmpy, respectively, with a "good" rating. These differences in corrosion rates are influenced by weld pool stability, the effects of gravity, and the potential for welding defects in each position. Thus, the 1G welding position provides the best welding quality and corrosion resistance performance and is therefore recommended for MIG welding of dissimilar materials, namely SS304 stainless steel and SS400 low-carbon steel.

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