GTAW WELDING DEFECTS ANALYSIS WITH WELDING CURRENT LEVEL AND TUNGSTEN DIAMETER PARAMETERS ON ST-37 STEEL

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Abstract

Gas Tungsten Arc Welding (GTAW) is a widely used welding method in the construction industry due to its high precision and efficiency. This study objective is to identify welding defects in ST-37 steel using parameters in tungsten electrode diameters and welding current. The tungsten electrode diameters used were 1.6 mm, 2.4 mm, and 3.2 mm, with current levels of 60 A, 80 A, and 100 A. After welding, a penetrant test was conducted according to ASME 2010 Section 6 standards to identify the types and number of welding defects. The test results indicated that the combination of a 3.2 mm tungsten electrode and a 60 A current produced the highest number of defects, with eight instances of porosity, cracks, and tungsten inclusions. In contrast, the same 3.2 mm electrode with a 100 A current resulted in the fewest defects, with only two defects identified, namely cluster porosity and tungsten inclusion. These findings suggest that higher current levels in GTAW welding tend to reduce the occurrence of welding defects in ST-37 steel, whereas lower current levels increase the likelihood of defects. This information is crucial for optimizing welding parameters in industrial applications.
Keywords: Current Level, Defects, Electrode, Gas Tungsten Arc Welding, ST-37 Steel

Introduction

Welding plays an indispensable role in today's construction industry, particularly in metalwork, where it is integral to both design and engineering processes. High technical proficiency is needed to produce quality welded joints, and one of the commonly employed welding methods is Gas Tungsten Arc Welding (GTAW). This technique uses a tungsten electrode to generate an electric arc, while filler material is introduced during the welding process. GTAW is versatile, as it can be applied in different welding positions and results in strong, reliable joints.

A critical aspect of the GTAW process is the level of current used, as it controls the amount of heat produced at the tip of the tungsten electrode. Higher currents produce more heat, leading to increased melting of both the base metal and the filler material, whereas lower currents generate less heat, affecting the melting process. Thus, selecting the appropriate current is essential for achieving effective welds. Other variables that impact welding quality include the penetration depth, arc voltage, type and size of the electrode, and welding speed. These factors all contribute to the likelihood of defects forming in the weld, such as porosity, cracking, and inclusions, which can negatively affect the overall quality of the welded structure.

Low-carbon steels, like ST 37, are widely used in general construction because they are easy to weld and resistant to cracking. ST 37 steel is particularly favored for its ductility, despite its low hardness and limited wear resistance. However, improper welding parameters can introduce various flaws, diminishing the weld quality. As such, it is important to understand how different welding conditions, such as current levels and electrode sizes, influence the formation of defects during the GTAW process.

This research objective is to explore how varying current levels and tungsten electrode diameters in the GTAW method affect the occurrence of welding defects in ST 37 steel. Specifically, the study focuses on defects like porosity, cracks, and inclusions, with the goal of identifying the optimal welding parameters to minimize these defects and enhance the overall quality of welded joints for industrial applications.

Methodology

1. Material Preparation: The material used consists of ST 37 steel plates, each measuring 100 mm in length, 60 mm in width, and 4 mm in thickness. A total of 54 plates were welded using the Gas Tungsten Arc Welding (GTAW) method, forming 27 welded plates. Additionally, three raw ST 37 steel plates, each measuring 200 mm x 60 mm x 4 mm, were prepared without welding, bringing the total number of plates to 30.
2. Equipment Preparation:
   a. GTAW Welding Machine: The welding process was carried out using a TIG 200 A-SA machine.
   b. Hose: Used to deliver gas from the cylinder to the welding torch.
   c. Regulator: Ensures gas pressure control and steady flow.
   d. Argon Gas: Protects the weld from atmospheric exposure.
   e. Tungsten Electrodes: EWTH-2 electrodes with diameters of 1.6 mm, 2.4 mm, and 3.2 mm were used.
   f. Filler Metal: ER70S-6 filler metal with a diameter of 2.4 mm.
   g. Steel Brush: Utilized for cleaning the material after welding.
   h. Pliers: For handling materials post-welding.

i. Personal Protective Equipment (PPE): Ensures safety throughout the welding process.
j. Grinder: Used to smooth the surfaces of the cut plates.
k. Vernier Caliper: Used to measure lengths and distances accurately.

3. Welding Process: After preparing materials and equipment, the GTAW process proceeds as follows:
   - Welding position: 1G
   - Joint design: Butt joint
   - Attach electrodes based on variation to the TIG torch.
   - Set the welding machine and adjust the current.
   - Perform tack welds to secure materials.
   - Weld using tungsten diameters (1.6 mm, 2.4 mm, 3.2 mm) and currents (60 A, 80 A, 100 A).
4. Weld Defect Testing:
   After welding, a penetrant test is conducted using Magnaflux Spotcheck cleaner (SKC-S), red penetrant (SKL-SP2), and developer (SKD-S2) according to ASME SECTION V ARTICLE 6 2011 standards. The steps are:
   - Apply cleaner (SKC-S) to clean the weld area.
   - Spray red penetrant (SKL-SP2) from 20-30 cm and wait for 5 minutes.
   - Wipe off the red penetrant with a cleaner-soaked cloth.
   - Apply developer (SKD-S2) from 30 cm to make defects visible.
   - Identify weld defects by observing the red marks.

Results and Discussion

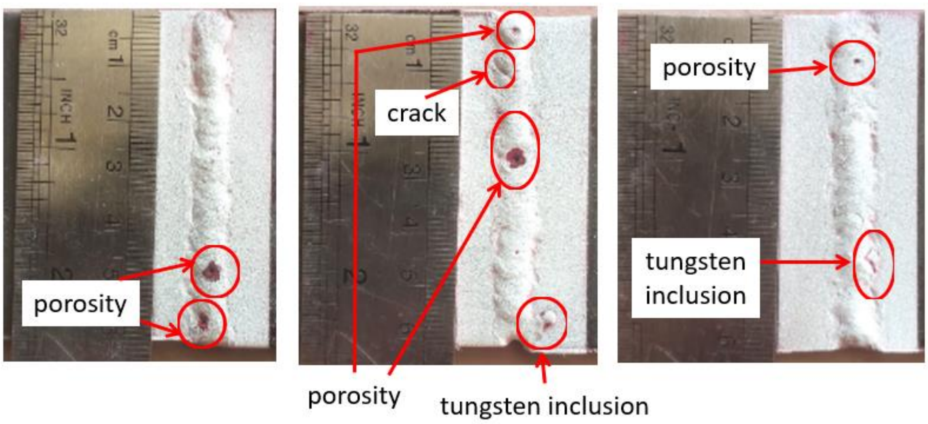

Figure 1. Visual identification of welding defects

Figure 1 illustrates the various welding defects observed in the specimens after the welding process was completed. Upon visual examination, the most common defects identified were porosity, tungsten inclusions, and cracks. These defects are typical in welding operations and can significantly compromise the integrity and durability of the welded material. Beyond these primary defects, a few specimens also displayed additional issues, including cluster porosity and undercut. Although these defects were less prevalent, their presence still contributes to the overall weakening of the welded joints, underscoring the critical need for precise control over welding parameters to avoid such imperfections.

The defects were systematically recorded, with each type of defect categorized according to the specific welding conditions under which it occurred. Each variation in welding parameters, such as electrode size and current level, was associated with a corresponding number of defects, which were carefully documented and analyzed. This information is visually summarized in Figure 2, where the data shows how adjustments in the tungsten electrode diameter and current levels influenced both the frequency and types of defects. By visualizing the relationship between welding parameters and defect occurrence, the graph provides valuable insights into the factors that contribute to defects during the welding process.

The findings from these observations are crucial for optimizing welding techniques, particularly in terms of selecting the right electrode size and current to minimize defects. This is especially important in applications where the strength and longevity of welded joints are critical. By carefully adjusting these parameters, welders can significantly reduce the incidence of defects, thereby improving the quality and reliability of the welds. Such optimization is vital in industries where high standards of structural integrity and material performance are essential, such as construction, automotive manufacturing, and aerospace engineering.

Furthermore, this analysis highlights the importance of continuous monitoring and adjustment of welding practices to account for the various factors that may contribute to defects. Small changes in electrode size or current can have a substantial impact on weld quality, emphasizing the need for thorough pre-welding assessments and ongoing quality checks during the welding process. In summary, understanding the interplay between welding parameters and defect formation is key to achieving higher-quality welds, reducing material failure, and enhancing overall safety in critical applications.

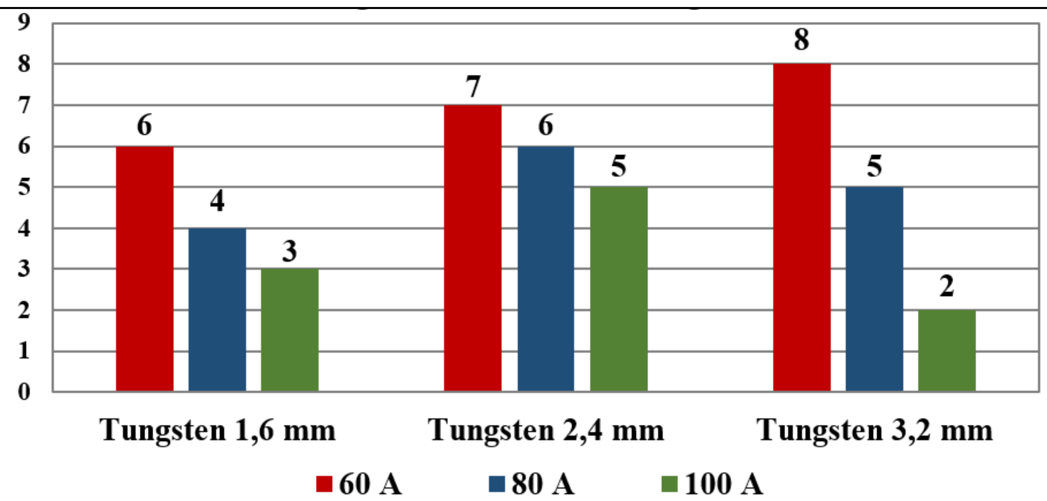

Figure 2. Number of defects in every variation

The variation in tungsten electrode diameters and current levels during the welding process has a notable impact on the formation of defects in the material. This study examined how different electrode sizes—1.6 mm, 2.4 mm, and 3.2 mm—combined with current levels of 60 A, 80 A, and 100 A, affect the welding of ST 37 steel using the GMAW method. The results revealed a clear connection between the electrode size, current, and the occurrence of welding defects.

When a 3.2 mm tungsten electrode was used with a 60 A current, the highest number of defects was recorded, with a total of 8 defects, including porosity, cracks, and tungsten inclusion. These types of defects compromise the structural integrity of the welded joint and increase the risk of failure in practical applications.

However, when the current was increased to 100 A while using the same 3.2 mm electrode, there was a significant reduction in defects, with only 2 instances noted, which consisted of cluster porosity and tungsten inclusion. The decrease in both the number and severity of defects suggests that a higher current level creates a more stable arc and improves the fusion of the materials, resulting in a cleaner weld with fewer imperfections.

Conclusion

The findings from the penetrant test reveal that using a 3.2 mm tungsten electrode with a 60 A current produced the highest incidence of welding defects, with a total of 8 distinct defects identified. These defects included porosity, cracks, and tungsten inclusions, all of which compromise the integrity of the weld. In contrast, increasing the current to 100 A while using the same 3.2 mm tungsten electrode significantly reduced the number of defects, with only 2 instances recorded. The defects at this higher current level were limited to cluster porosity and tungsten inclusions. These results underscore the strong influence that both tungsten electrode diameter and current level have on the formation and frequency of welding defects in ST 37 steel. The data clearly show that higher current levels tend to minimize defects, regardless of the electrode size, by promoting more efficient material fusion and a more stable welding arc. Conversely, lower current levels result in more frequent and severe defects, particularly with larger tungsten electrodes, likely due to insufficient heat for proper fusion and the potential for instability in the welding process. Overall, these findings suggest that controlling current levels is critical to reducing defects and improving weld quality. Industrial applications that require high-performance, defect-free welds should prioritize using higher current settings, especially when working with larger electrode diameters, to ensure a more reliable and durable final product. These insights provide valuable guidance for optimizing welding parameters, which is essential for enhancing the structural performance of welded joints in various engineering and construction applications.

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References

1. Ismail, D. Santoso, and R. Widodo, "Comparative study of welding techniques on tensile strength of low-carbon steel," Indonesian J. Eng. Innov., vol. 18, no. 3, pp. 201-208, Sept. 2021.
2. Rahman, T. Setiawan, and F. Taufik, "Study on microstructural and mechanical properties of welded joints in carbon steel using GTAW process," J. Eng. Technol., vol. 19, no. 2, pp. 113-120, Mar. 2021.
3. ASTM International, "ASTM E8/E8M-13a: Standard Test Methods for Tension Testing of Metallic Materials," West Conshohocken, PA, USA: ASTM International, 2013.
4. F. A. Lestari, "Application of GTAW for enhancing mechanical properties in industrial steel joints," J. Steel Constr., vol. 29, no. 2, pp. 221-229, Feb. 2022.
5. Sugiarto, R. Hartono, and S. Pranoto, "Influence of welding current on tensile strength in ST 37 steel using GTAW," Indonesian J. Mater. Sci. Eng., vol. 14, no. 1, pp. 49-55, Jan. 2019.
6. L. Putra, D. Kurniawan, and I. Wibisono, "Effect of electrode diameter and current on mechanical properties of welded steel," Mater. Sci. Eng. Conf. Ser., vol. 541, no. 3, pp. 145-152, Oct. 2021.
7. M. Hartanto, "Welding techniques for low-carbon steel: A study on GTAW process parameters," J. Mater. Process. Technol., vol. 25, no. 1, pp. 102-109, Jan. 2024.
8. M. Kurniawan, "Tensile testing standards for welded joints using ASTM E8 protocol," J. Metall. Eng., vol. 17, no. 4, pp. 411-417, Nov. 2020.
9. P. Suryadi, F. Nugraha, and T. Sukmana, "The effect of current variation on tensile strength in GTAW process for ST 37 steel," Int. J. Weld. Sci., vol. 12, no. 1, pp. 35-42, Mar. 2019.
10. S. Mulyana and E. Wibowo, "Optimization of welding parameters to improve tensile strength in low-carbon steel joints," Indonesian J. Weld. Tech., vol. 11, no. 4, pp. 307-314, Dec. 2022.
11. S. Purnomo and B. Susanto, "Mechanical properties analysis of GTAW-welded ST 37 steel with various current levels," Indonesian J. Eng. Sci., vol. 14, no. 2, pp. 165-171, Aug. 2018.
12. T. Wijaya, F. Lestari, and A. Sudarma, "Study on the optimization of welding parameters in low-carbon steel using GTAW," Indonesian J. Manuf. Sci., vol. 21, no. 3, pp. 237-243, Sept. 2023.

13. W. J. Adi, R. Mahendra, and D. Firmansyah, "Performance evaluation of different electrode diameters in GTAW welding of ST 37 steel," J. Eng. Technol., vol. 20, no. 2, pp. 129-137, June 2022.
14. Y. Nugroho, "Welding technique development for enhanced mechanical performance in GTAW," J. Adv. Weld. Technol., vol. 22, no. 2, pp. 157-163, Apr. 2020.
15. Y. Suparman, A. Hidayat, and P. Nugraha, "Effect of welding parameters on the mechanical properties of low-carbon steel," J. Mech. Eng. Sci., vol. 13, no. 3, pp. 267-274, Aug. 2020.