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ANALYSIS OF TENSILE STRENGTH IN GTAW WITH WELDING CURRENT AND TUNGSTEN DIAMETER VARIATIONS ON ST-37 STEEL

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Abstract

Gas Tungsten Arc Welding (GTAW) is commonly used in construction due to its precision and efficiency. This research focuses on assessing the tensile strength of ST 37 steel welded using GTAW with different tungsten electrode diameters and current settings. The electrode sizes used were 1.6 mm, 2.4 mm, and 3.2 mm, paired with current levels of 60 A, 80 A, and 100 A. Tensile strength testing was performed following ASTM E8 standards. The results indicated that the 3.2 mm electrode with 100 A current produced the highest tensile strength at 43.13 kg/mm², while the 1.6 mm electrode with 60 A current yielded the lowest tensile strength at 29.75 kg/mm². These findings demonstrate that higher current levels in GTAW welding result in greater tensile strength for ST 37 steel, offering valuable guidance for optimizing welding parameters in industrial settings.

Keywords: Current Level, Electrode, Gas Tungsten Arc Welding, ST37 Steel, Tensile Strength.

Introduction

Welding plays a pivotal role in modern construction, especially in metal structures where durable, high-quality joints are essential. Among the various welding techniques, Gas Tungsten Arc Welding (GTAW) stands out for its precision and ability to produce robust welds. This method employs a tungsten electrode to generate an electric arc, with filler material added to the joint during the process. GTAW is highly versatile, suitable for a range of welding positions, and renowned for creating strong, reliable connections. One of the most crucial factors in this process is the welding current, which directly affects the amount of heat produced at the electrode tip. Higher currents generate more heat, enhancing the melting of both the base and filler metals, while lower currents yield less heat, potentially influencing the melting efficiency. Additional factors such as penetration depth, arc voltage, electrode diameter, and welding speed also contribute significantly to the overall strength of the weld. Therefore, selecting the optimal current and electrode size in the GTAW process is key to ensuring the production of high-quality welded joints.

Low-carbon steel alloys like ST 37 are widely favored in the construction industry due to their excellent weldability and resistance to cracking. ST 37 steel, in particular, is characterized by its high ductility, which makes it relatively easy to weld. However, it has some limitations, such as lower hardness and limited wear resistance. Despite these constraints, its softness and weldability make it an ideal material for various structural applications in construction.

This research aims to explore the influence of different welding current levels and tungsten electrode diameters in the GTAW process on the mechanical properties of ST 37 steel, with a primary focus on tensile strength. By understanding how variations in these parameters impact the weld's mechanical performance, the study provides valuable insights into optimizing welding techniques for this widely used material in 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. Tensile Testing: After preparing specimens based on ASTM-E8 standards, the tensile test is conducted at the Materials Lab of Universitas 17 Agustus 1945 Surabaya. Steps are:
   1. Prepare specimens.
   2. Place specimens in the tensile testing machine.
   3. Set the load scale.
   4. Start pulling the specimen until it fractures.
   5. Measure elongation and load during the process via connected software.

Results and Discussion

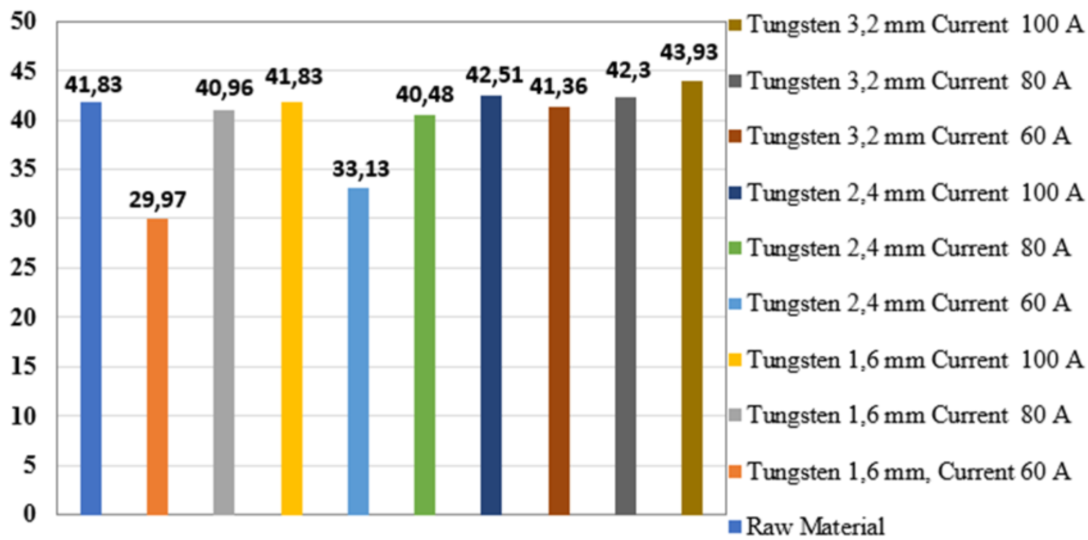

Figure 1. Average of Ultimate Tensile Strength in every variation (kg/mm^2)

Figure 1 illustrates the relationship between the average maximum tensile strength of ST-37 steel and variations in tungsten electrode diameters and current levels during Gas Tungsten Arc Welding (GTAW). The data clearly demonstrates that welding parameters, such as electrode size and current, significantly impact the resulting tensile strength, which is a critical measure of the weld's mechanical integrity.

The highest tensile strength of 43.93 kg/mm² is achieved using a 3.2 mm tungsten electrode at a 100 A current. This result highlights the importance of both sufficient heat generation and material fusion in producing high-strength welds. A larger electrode, combined with a high current, generates a greater heat input, which enhances the melting of both the base and filler metals, leading to stronger bonds at the joint. This combination minimizes potential voids or inconsistencies at the weld interface, which would otherwise weaken the structure. The higher current likely enables a deeper penetration of the weld, allowing for a more uniform fusion of the materials. These optimal welding conditions create a strong, defect-free weld, ideal for applications requiring high mechanical strength, such as in structural construction or heavy manufacturing industries.

On the other hand, the lowest tensile strength, 29.97 kg/mm², is observed with the use of a 1.6 mm tungsten electrode at a 60 A current. This combination does not provide sufficient heat for effective material fusion. Smaller electrode diameters inherently restrict the amount of current they can carry, limiting the heat generation needed for deep material penetration. The reduced heat output affects the melting process of both the base metal and the filler material, leading to incomplete fusion or insufficient bonding at the weld interface. This can result in weaker weld joints that are more susceptible to defects like cracks or porosity, which reduce the overall tensile strength. In industrial applications, such weaknesses could lead to premature failure of welded components, especially under stress or load, making this combination of parameters less suitable for critical welding tasks.

Another notable observation from the data is the performance of a 2.4 mm tungsten electrode with a 100 A current, which produces a tensile strength of 42.51 kg/mm², only slightly lower than the highest value. This result suggests that even with a slightly smaller electrode, the use of higher current can still produce a strong weld. The key factor here appears to be the current level, which compensates for the smaller electrode size by providing enough heat to achieve good material fusion. This highlights that while electrode size is important, the current plays a more dominant role in determining weld quality. However, when the same 2.4 mm electrode is paired with a lower current of 60 A, the tensile strength drops to 40.48 kg/mm². This further reinforces the idea that lower currents do not provide sufficient heat for optimal fusion, even if the electrode size is suitable for carrying higher currents.

The overall trend in the data shows that as both electrode diameter and current increase, so does the tensile strength of the weld. This suggests that higher heat input during the welding process results in more efficient bonding of the materials, producing welds with higher mechanical integrity. The increase in tensile strength with higher currents and larger electrodes likely results from deeper penetration of the weld, more thorough melting of the base metal, and improved interaction between the base and filler metals. These factors reduce the likelihood of imperfections at the weld site, such as incomplete fusion or residual stresses, which can compromise the strength of the joint.

From an industrial perspective, the implications of these findings are significant. In applications where high tensile strength is a critical requirement, such as in construction, automotive manufacturing, or heavy machinery, careful selection of welding parameters is essential. Using larger electrodes and higher currents can improve the quality of the weld and ensure that it meets the mechanical demands of the application. Conversely, smaller electrodes and lower currents may be suitable for tasks that do not require such high strength or where fine control of heat input is needed, such as welding thinner materials or performing precision welds on delicate components.

Conclusion

In conclusion, this research demonstrates that the choice of welding parameters—particularly tungsten electrode diameter and current level—plays a decisive role in determining the tensile strength of ST-37 steel welds. The findings suggest that for high-strength applications, larger electrodes paired with higher current levels provide the best results, producing stronger, more reliable welds. However, for applications where lower mechanical strength is acceptable or heat control is critical, smaller electrodes and lower currents may be employed, though they may compromise the overall tensile strength of the weld. This understanding is vital for optimizing welding processes in various industrial sectors to ensure the durability and performance of welded structures.

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