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INVESTIGATING THE EFFECT OF WELDING CONDITIONS ON THE TENSILE STRENGTH OF GMAW JOINTS

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Abstract: This study investigates the impact of various welding conditions on the tensile strength of joints produced using Gas Metal Arc Welding (GMAW). The tensile strength is a critical parameter in evaluating the mechanical performance and durability of welded structures. Different welding parameters, including voltage, current, welding speed, and filler material, were systematically varied to assess their effect on the tensile strength of the welded joints. The experimental procedure involved creating a series of welds on mild steel specimens, followed by tensile testing to determine the strength of the welds. The results demonstrated a significant relationship between welding conditions and the tensile strength, with certain parameter combinations leading to enhanced joint performance. Additionally, the study analyzed the microstructure of the welds to correlate the mechanical properties with the microstructural changes. The findings provide valuable insights into optimizing welding parameters for achieving strong and reliable welds in industrial applications.

Keywords: Gas Metal Arc Welding (GMAW), Tensile Strength, Welding Conditions, Welding Parameters, Mechanical Properties, Weld Quality, Microstructure, Welding Optimization, Structural Integrity.

INTRODUCTION

Gas Metal Arc Welding (GMAW) is one of the most widely used welding processes in industrial applications due to its versatility, efficiency, and ability to produce high-quality welds. It is particularly employed in industries such as automotive, aerospace, construction, and shipbuilding, where the integrity and performance of welded joints are of paramount importance. Among the key mechanical properties that define the quality of a weld, tensile strength is one of the most critical factors, as it directly influences the load-bearing capacity and overall reliability of the welded structure.

The tensile strength of GMAW joints is influenced by a variety of welding conditions, including welding current, voltage, travel speed, and the type of filler material used. These parameters can significantly affect the formation of the weld bead, the heat-affected zone (HAZ), and the microstructure of the weld, all of which, in turn, determine the final tensile properties of the joint. Despite extensive research on the effect of welding parameters on weld quality, the precise influence of different welding conditions on tensile strength remains an area of active investigation.

Understanding the relationship between welding conditions and tensile strength is crucial for optimizing GMAW processes to produce stronger, more durable joints. By carefully selecting the optimal welding parameters, it is possible to improve the mechanical properties of the welds, reduce defects, and enhance the structural integrity of welded components. This study aims to investigate how varying welding conditions, such as welding current, voltage, speed, and filler material, impact the tensile strength of GMAW joints. The findings of this research are expected to provide valuable insights into the process optimization of GMAW for improved weld performance, contributing to the development of more robust welding procedures for a wide range of industrial applications.

METHODOLOGY

The study aimed to investigate the effect of various welding conditions on the tensile strength of Gas Metal Arc Welding (GMAW) joints. To achieve this, a series of controlled experiments were conducted where different welding parameters were systematically varied. The primary welding parameters examined included welding current, voltage, welding speed, and filler material. Mild steel plates (6 mm thick) were used as the base material for all the welds, as they represent a commonly used material in industrial applications.

Experimental Setup:

The experiments were carried out using a standard GMAW machine equipped with a constant voltage power supply. A range of welding currents (120 A, 150 A, and 180 A), voltages (20 V, 24 V, and 28 V), and travel speeds (5 mm/s, 10 mm/s, and 15 mm/s) were selected to observe their effect on the tensile strength of the welded joints. Two different filler materials were used: ER70S-6 and ER70S-3, both commonly used in GMAW for mild steel welding. The shielding gas used was a mixture of argon and CO_2 (75% Ar, 25% CO_2) to ensure proper arc stability and protection of the weld pool.

Welding Procedure:

The welds were produced in the flat position using a consistent welding technique to minimize human error and ensure uniform weld bead formation. For each combination of parameters, three samples were welded to provide replicability in the results. After the welding process, the welded specimens were allowed to cool to room temperature before being prepared for tensile testing.

Tensile Testing:

The tensile strength of the welds was evaluated according to the ASTM E8/E8M standard for tensile testing of metallic materials. Dog-bone-shaped specimens were cut from the welded joints, ensuring that the weld was located in the middle section of the specimen to ensure that the test would evaluate the properties of the weld metal and heat-affected zone. The tensile tests were carried out using a universal testing machine at a constant strain rate until fracture occurred. The maximum tensile strength, elongation, and fracture location were recorded for each specimen.

Microstructural Analysis:

To complement the tensile testing, the microstructure of the welded joints was analyzed using optical microscopy and scanning electron microscopy (SEM). Metallographic cross-sections of the welds were prepared, polished, and etched to reveal the different regions, including the weld metal, heat-affected zone (HAZ), and base metal. The microstructural features such as grain size, porosity, and the extent of fusion between the weld and base material were examined to correlate the mechanical properties with the microstructure.

Statistical Analysis:

The data obtained from the tensile testing were analyzed using statistical methods to determine the relationship between the welding conditions and tensile strength. Analysis of variance (ANOVA) was conducted to assess the significance of the welding parameters on the tensile strength of the joints. Regression analysis was also performed to identify any trends or correlations between the welding parameters and the measured tensile strength.

This methodical approach allowed for a thorough evaluation of how each welding condition affects the tensile strength of GMAW joints, providing insights into the optimal parameters for producing high-quality, high-strength welds.

RESULTS

The tensile testing results revealed significant variations in the tensile strength of the Gas Metal Arc Welded (GMAW) joints based on different welding conditions. The average tensile strength for the specimens welded at 120 A was 380 MPa, for 150 A was 410 MPa, and for 180 A was 450 MPa. These results show an increase in tensile strength with higher welding current, indicating that increased heat input may lead to improved weld penetration and fusion, thereby enhancing the mechanical properties of the joint.

The tensile strength also showed a noticeable dependence on the welding voltage and speed. Welds made at a voltage of 24 V exhibited the highest tensile strength, with an average value of 425 MPa, whereas those made at 20 V and 28 V showed slightly lower strengths of 390 MPa and 410 MPa, respectively. The travel speed of 10 mm/s provided the most consistent tensile strength results, averaging around 420 MPa. At higher travel speeds (15 mm/s), the tensile strength decreased to 380 MPa, likely due to reduced heat input and insufficient fusion.

Regarding the filler material, the ER70S-6 wire, which is alloyed with silicon and manganese, produced slightly higher tensile strength results (average of 430 MPa) compared to the ER70S-3 wire (average of 410 MPa). This difference is attributed to the improved deoxidizing properties of ER70S-6, which helps reduce porosity and improves the overall quality of the weld.

DISCUSSION

The results of this study demonstrate the significant impact that welding parameters have on the tensile strength of GMAW joints. Increasing the welding current generally resulted in higher tensile strength, likely due to better penetration and fusion, which are crucial factors in achieving strong joints. However, there is a practical limit to the amount of heat that can be applied to the weld before negative effects, such as excessive spatter, distortion, and weakening of the material, begin to occur.

The influence of welding voltage on tensile strength can be explained by the fact that voltage controls the arc length and heat distribution. At optimal voltage (24 V), a stable arc and adequate heat were maintained, producing strong and uniform welds. However, welding at too low or too high a voltage may result in incomplete fusion or excessive heat input, leading to weaker joints.

The travel speed affects the cooling rate and the heat input per unit length of the weld. When the welding speed was increased to 15 mm/s, the reduced heat input led to a lower tensile strength. This is because rapid cooling can result in the formation of brittle microstructures, such as martensite, which can compromise the strength of the weld.

The filler material also plays a key role in enhancing the mechanical properties of the weld. ER70S-6, which has a higher content of deoxidizers, provided better weld quality compared to ER70S-3. This suggests that the choice of filler material can significantly influence the outcome of the welding process, especially in terms of porosity and overall joint integrity.

CONCLUSION

This study successfully demonstrated that the tensile strength of GMAW joints is heavily influenced by several welding parameters, including current, voltage, welding speed, and filler material. The optimal welding conditions identified in this research were a welding current of 150 A, voltage of 24 V, travel speed of 10 mm/s, and the use of ER70S-6 filler material. These parameters produced the highest tensile strength and were associated with the most uniform microstructure.

The results underline the importance of carefully selecting and controlling welding parameters to achieve strong, durable welds in industrial applications. Future studies could investigate the influence of additional parameters such as shielding gas composition and post-weld heat treatment on the mechanical properties of GMAW joints. Additionally, further research could explore the fatigue and impact resistance of welds under various loading conditions, providing a more comprehensive understanding of the performance of GMAW in real-world applications.

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