Investigation of the Effects of Gas Metal Arc Welding Parameters on Tensile Strength

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Abstract: ***In this study, the effects of arc current and voltage on the tensile strength of S700MC steel welded using the Gas Metal Arc Welding GMAW method were examined. Parameters other than arc current and voltage were kept constant, and welding connections were produced according to a designed experimental plan. Tensile tests revealed that high arc voltage, which leads to a longer arc length, increased the weld seam width while decreasing penetration, thereby reducing tensile strength. Shorter arc lengths were found to produce more robust weld joints, with tensile strength values approximately 15 higher compared to those with longer arc lengths.***

Keywords: Gas Metal Arc Welding Parameters, Welding Current, Welding Voltage, Tensile Testing

1. Introduction

Steel used in welded fabrication must have high weldability. This is especially crucial in machinery such as cranes that operate under severe conditions, where the quality of welding is paramount. The quality of a weld connection fundamentally depends on several factors: the type of welding, welding parameters, mechanical properties, chemical composition of the welding metal, and the heat affected zone. (ERYÜREK, B., 2007).

In the manufacturing industry, various welding methods are employed, which can be broadly classified into two types based on the process (Aslanlar, S., 2009)

- Pressure Welding
- Fusion Welding

Among fusion welding methods, shielded metal arc welding (SMAW), being one of the earliest welding techniques and applicable with simple equipment, was used for a long period. However, due to its costly and less efficient characteristics—such as the need for skilled welders for reliable joints and limited welding speed—there was a shift towards gas metal arc welding (GMAW). This semi - automatic method, also classified under fusion welding, became preferred for its advantages over manual shielded metal arc welding. (Tülbentçi, K., 1990)

Gas metal arc welding (GMAW) offers several advantages, including high reliability, applicability in all positions, ease of use, low cost, and high productivity. (M. Ericson, R. Sandström, 2003). The principle of this welding method involves continuously feeding a bare electrode wire with the aid of a mechanical setup and supplying current very close to the arc zone to increase the current capacity and melting power of the wire. In this process, the protective gas assumes the role of the flux used in shielded metal arc welding.

However, one disadvantage of GMAW is the potential impact of environmental factors, such as wind, during outdoor welding operations. Such air currents can reduce the effectiveness of the protective gas, decrease weld quality, and complicate the welding process. Increasing the flow rate of the protective gas might offer a temporary solution, but it can negatively affect weld quality and increase production costs. (Hooda, A., Dhingra, A., Sharma, S., 2012).

In his 2009 study, Kul A. investigated the effects of welding parameters on weld quality and penetration in industrial welding robots. The study identified that the primary factor influencing changes in welding current values was the wire feed speed. Kul observed that altering the welding speed did not affect the applied welding current. Additionally, the study found that an increase in wire feed speed led to higher welding current and increased weld pool temperature. This could result in excessive melting and, depending on thickness, phenomena such as burn - through or root excess. Conversely, a decrease in wire feed speed resulted in lower current, insufficient heat transfer to the weld pool, and consequently, penetration issues due to inadequate melting. (Kul A.2009).

The significance of this study lies in its potential to optimize welding parameters for enhanced tensile strength in industrial applications, thereby improving the reliability and performance of welded structures.

2. Materials and Methods

In this study, connections were made using MIG - MAG gas metal arc welding methods with S700MC grade material, which is commonly used in machine manufacturing. These connections were examined for penetration and weld profiles, and subjected to tensile tests for strength evaluation. A mixed gas of 82% Argon and 18% CO_2, frequently used in MIG - MAG applications, was employed as the shielding gas. The reason for using this gas mixture is that Argon, being 1.4 times heavier than air, provides more effective coverage of the weld pool. Additionally, due to Argon's lower thermal conductivity compared to other gases, it results in higher penetration at the center of the weld profile. The addition of CO_2 to Argon aims to enhance arc stability and improve lateral penetration. (Ahmet Akın.2015)

To determine the effects of welding parameters on the strength of the connections, an experimental plan was developed. Since changes in arc current and arc voltage influence the type of arc and the deposition rate, the voltage and current values used in our experiments were grouped for analysis. Voltage changes also affect the arc length; therefore, to make the differences between voltage levels more distinctive, three types of arcs were established based on voltage values: short arc, medium arc, and long arc.

Table 1: Experimental Work Plan

Parameter No	Arc Type	Arc Length	Arc Voltage (Volt)	Wire Feed Speed (m/dk)	Arc Current (Amperes)
1	Short	35	21, 6	8	216
2	Short	35	22, 9	10	255
3	Short	35	25, 0	12	269
4	Medium	50	26, 0	8	210
5	Medium	50	28, 5	10	240
6	Medium	50	29, 9	12	266
7	Long	65	29, 7	8	270
8	Long	65	32, 1	10	277
9	Long	65	34, 0	12	291

Table 2: Gas Metal Arc Welding Parameters and Values Held Constant During Experiments

Electrode Type	Electrode Diameter (mm)	Contact Tip - to - Weld Distance (mm)	Nozzle - to - Workpiece Distance (mm)	Torch Angle (degrees)
SG2	1, 2	18	12	20°

Table 3: Gas Metal Arc Welding Parameters and Values Held Constant During Experiments

Shielding Gas Type	Shielding Gas Flow Rate (lt/dk)	Welding Speed (m/dk)	Welding Direction
%82 AR - %18 CO2	12 - 14	40	Right

For the welding process, each of the materials to be joined was first subjected to a single root pass using the same parameters. Following this, a single fill pass was applied according to the experimental parameters (Figure 1). The interpass temperature for all test samples was maintained at a standard 250 °C.

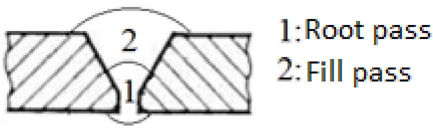

Figure 1: Root Pass and Fill Pass

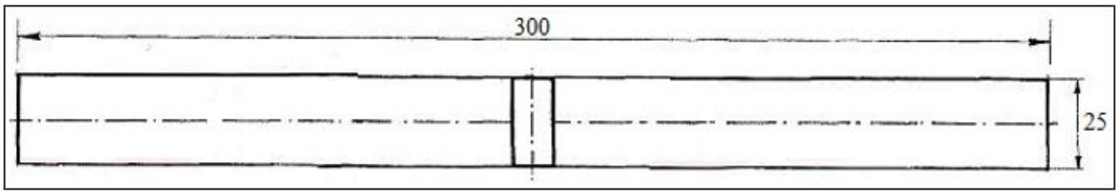

Figure 2: Sample of Tensile Test

Figure 3: A View of the Tensile Test

For samples obtained with each parameter, the weld bead width and weld bead height were measured. These measurements were used to examine the conditions of vertical and horizontal penetrations (Table 4).

3. Experimental Results

To investigate the effects of voltage and current variations on the strength of the connection, three tensile samples were taken from each connection and subjected to tensile tests in a single direction, at a constant temperature, and at a reasonably constant speed. The average of the three obtained values was considered as the tensile and rupture values of the sample combined with that parameter.

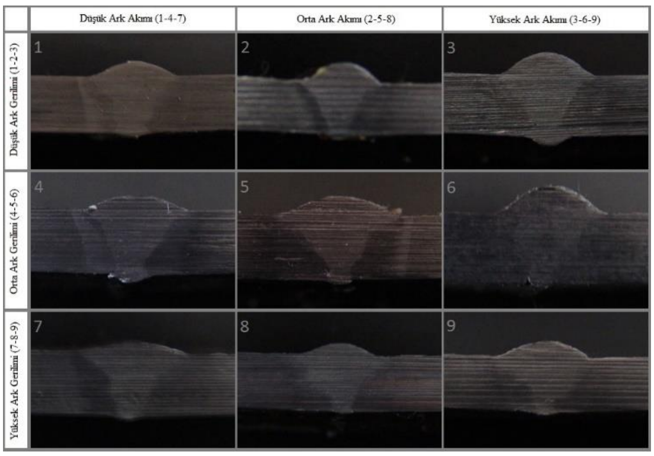

Figure 4: Macro Images of Weld Penetration According to Arc Current and Voltage

Table 4: Welding Seam Widths and Heights According to Parameter Order

Par. No	Wire speed (m/dk)	Arc Current (Amper)	Arc type	Arc voltage (Volt)	Weld Bead Width (mm)	Weld Bead Height (mm)	Average Weld Bead Width According to Arc Type (mm)	Average Weld Bead Height According to Arc Type (mm)
1	8	216	Short	21, 6	8, 84	1, 64	9, 13	2, 04
2	10	255	Short	22, 9	9, 10	2, 17		
3	12	269	Short	25, 0	9, 47	2, 33		
4	8	210	Medium	26, 0	9, 79	1, 35	10, 06	1, 85
5	10	240	Medium	28, 5	10, 56	1, 75		
6	12	266	Medium	29, 9	9, 85	2, 46		
7	8	270	Long	29, 7	10, 42	0, 95	10, 48	1, 41
8	10	277	Long	32, 1	10, 49	1, 35		
9	12	291	Long	34, 0	10, 53	1, 93		

The weld penetrations of samples obtained with each parameter were examined, and the results are presented in Table 5.

Table 5: Weld Penetrations According to Parameter Order

Par. No	Wire speed (m/dk)	Arc Current (Amper)	Arc type	Arc voltage (Volt)	Vertical Penetration	Horizontal Penetration
1	8	216	Short	21, 6	Very good	Good but inconsistent
2	10	255	Short	22, 9	Very good	Good and consistent
3	12	269	Short	25, 0	Very good	Very good and consistent
4	8	210	Medium	26, 0	Good	Good but inconsistent
5	10	240	Medium	28, 5	Good	Average and inconsistent
6	12	266	Medium	29, 9	Medium	Average and inconsistent
7	8	270	Long	29, 7	Medium	Average and inconsistent
8	10	277	Long	32, 1	Medium	Average and inconsistent
9	12	291	Long	34, 0	Poor	Average and inconsistent

The results of the tensile tests conducted after the welding operations are presented in Table 6

Table 6: Tensile Test Results According to Parameter Order

Par. No	Wire speed (m/dk)	Arc Current (Amper)	Arc type	Arc voltage (Volt)	Tensile Value (kN)	Break Value (kN)	Average Tensile Value (kN)	Average Break Value (kN)
1	8	216	Kısa	21, 6	109, 8	105, 0	111, 8	104, 2
2	10	255	Kısa	22, 9	110, 2	107, 5		
3	12	269	Kısa	25, 0	115, 3	100, 0		
4	8	210	Orta	26, 0	112, 7	102, 7	108, 9	96, 5
5	10	240	Orta	28, 5	107, 7	98, 7		
6	12	266	Orta	29, 9	106, 3	88, 0		
7	8	270	Uzun	29, 7	95, 2	76, 3	97, 8	82, 5
8	10	277	Uzun	32, 1	100, 5	91, 0		
9	12	291	Uzun	34, 0	97, 8	80, 2		

4. Results and Discussions

When examining the results obtained from samples joined with medium arc voltage, no significant difference in tensile values was observed compared to those joined with low arc voltage. The more noticeable aspect here is the decrease in tensile values with the increase in arc current. This is because increasing the arc current, which involves increasing the wire feed rate, leads to an increase in deposition amount, weld bead height, and width. As a result, the weld pool's surface area for heat transfer increases, leading to faster cooling. This rapid cooling results in reduced vertical and horizontal penetration as the depth increases, causing internal stresses and a decrease in tensile values. This can be easily observed by examining parameters 4, 5, and 6. Therefore, while increasing the arc current improves penetration and tensile values at low arc voltage, it decreases penetration and tensile values at medium arc voltage and also results in considerable inconsistency in penetration.

The tensile value results obtained from samples joined with high arc voltage were found to be approximately 10 - 15% lower on average compared to those joined with low and medium arc voltages. This is due to the long arc length resulting from high arc voltage, which leads to inadequate and poor penetration compared to other arc lengths as the weld depth increases. Additionally, the longer arc length results in a larger weld bead width compared to other arc lengths, creating another disadvantage by increasing the surface area available for heat transfer. This leads to rapid cooling and high internal stresses, which in turn reduces tensile strength. The generally inadequate penetration caused by the long arc length, combined with rapid cooling and high internal stresses due to the increased weld bead width, makes the tensile values of samples obtained with parameters 7, 8, and 9 significantly weaker compared to those obtained with other arc lengths. Increasing the arc current to compensate for the inadequate penetration caused by the long arc length does not resolve the issue but only increases the deposition amount, and consequently, the weld bead width and height.

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