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Investigation of Mechanical Properties of St52 and S460MC Steels Joined by Gas Welding

Yiğit Okuroğullari[1], Oktay Çavuşoğlu[1,2*], Mümin Tutar[3] and Hakan Aydın[1]

0000-0002-6314-0399 1, 0000-0002-2826-1814 2, 0000-0002-7286-3433 3, 0000-0001-7364-6281 4

[1] *Mechanical Engineering Department, Faculty of Engineering, Bursa Uludağ University, Bursa, 16035, Turkey*
[2] *TOFAŞ, Turkish Automobile Factory, R&D Center, Bursa, Turkey*
[3] *Technology Sciences Department, Air NCO Higher Vocational School, National Defense University, İzmir, 35414, Turkey*

Abstract

In this study, the effect of the changes in welding parameters on the tensile strength, which is one of the mechanical properties of the steels, was investigated in the robotic gas arc welding method applied to St52 and S460MC steels, which are widely used in the industry. As a result of the experiments carried out within the scope of the study, it was aimed to determine the optimum parameter values for the MAG welding method. St52 and S460MC materials were used in the experiments. An experimental design was created in order to carry out the experiments in the most accurate way. Parameter values are placed in this created experimental design. As a result of the experiments performed according to the created the experimental design, the optimum parameter values were examined, welding processes were applied with the selected values, and the improvements in the welding quality were determined by subjecting the welded samples to the tensile test. The optimum welding parameters providing the best mechanical properties were 25 V, 7 mm/sec and 13 mm/sec for the arc voltage, wire feed speed and welding speed, respectively.

Keywords: Welding, MAG, Mechanical properties, Welding parameters

Research Article

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* Corresponding author
Oktay Çavuşoğlu
oktaycavusoglu@uludag.edu.tr
Address: Mechanical Engineering Department, Faculty of Engineering, Bursa Uludağ University, Bursa, Turkey
Tel:+903122028653

1. Introduction

Today, welding, as a joining method, is frequently for joining steel sheets in many industries such as automotive, machine production and aviation [1-4]. The electric arc welding method applied under shielding gas is called gas arc welding. In this method, the consumable electrode wire is fed into the welding area after the arc is formed [5]. Shielding gas is used to protect the welding area from oxygen which causes the occurrence of oxide phases [6-7]. The selection of welding parameters is one of the most important factors on the weld quality. In the literature, many studies have been reported on joining the two pieces of steel sheets with electric arc welding [8-12]. Nabendu G. et al. [13] optimized the process parameters of gas metal arc welding on AISI409 stainless steel by using the Taguchi method. Ghalib A. et al. [14] investigated the effect of different welding parameters on the weld quality in the gas metal arc welding process. The variable parameters in this study were welding current, arc voltage and welding speed. It was determined that the penetration depth increased when the welding current parameter was increased. Variable welding parameters have changed the grain boundaries of the microstructure. Kumar S. et al. [15] carried out an optimization study for the MIG welding process parameters by using the gray-based Taguchi method on preheated AISI 1018 mild steel. It has been determined that the most effective parameter affecting the tensile properties of AISI 1018 mild steel is the preheating temperature. This was followed by welding current and welding voltage. Moravec J. et al. [16] studied the effect of heat input on the distribution of temperature cycles in the HAZ of S460MC welds in MAG welding. Their study, shows the influence of heat input value on the weld pool geometry. Akkuş et al. [17] studied the effects of shielding gas and welding speed on the tensile strength of welded structural steels. They observed that shielding gas and welding speed affect the tensile strength of structural steels joined by MAG welding method. In this study, St52 steels, and S460MC steels, which are widely used in the automotive industry, were combined with gas arc welding. Tensile test was applied to determine mechanical properties. As a result of the analysis and experiments, the basic parameters affecting the welding quality were examined and the welding parameters providing the best weld quality were determined.

2. Materials and Research Method

2.1 Materials

In this study, St52 and S460MC grades of sheet materials with a thickness of 3 mm were used. The tensile strengths of St52 and S460MC materials are in the range of 540-680 MPa and 520-670 MPa, respectively. The SG2 material used as welding wire has a tensile strength of 520 MPa on average. The strength of the work piece material should be higher than the strength of the weld material as a result of the tensile test, as it is preferred that the failure occurs at the weld joint.

Table 1. Chemical composition of S460MC & St52 Steel

Material	C %	Si %	Mn %	P %	S %	Al %	Nb %	V %	Ti %
S460MC	0.12	0.5	1.6	0.025	0.015	0.01	0.09	0.2	0.15
St52	0.22	0.5	1.6	0.035	0.035	0.02	0.01	-	-

Table 2. Chemical composition of SG2 welding wire

Material	C %	Si %	Mn %	P %	S %	Cu %
SG2	0.07-0.1	0.7-1.0	1.4-1.6	<0.025	<0.025	<0.3

2.2 Experimental Setup

While establishing the experimental method to determine the effects of welding parameters on the joint strength, current and voltage changes from the gas arc welding parameters are affect the arc type and the amount of deposition. The voltage parameter, which is affecting the arc length directly, used in the experiments has been examined in groups. In order to group the variations in arc length, three different arc groups were selected as long, medium and short according to the current and voltage values to be applied in the welding process. The wire feed speed was also examined at three different values. In addition, the effect of welding speed on weld strength was investigated. To investigate the effects of welding parameters on 2 different materials, 3 levels of welding voltage, 3 levels of wire feed speed and 3 levels of welding speed were used. Other parameters were kept constant. The experimental design performed is shown in Table 3. For each parameter set, 210x300x3 mm welded sheets were manufactured to obtain the test samples. Tensile test samples were cut by laser cutting from welded sheets. The schematic shape of the tensile sample is given in Figure 2. The samples were welded in Atikerweld brand MAG welding machine. The tensile test was carried out at room temperature at a speed of 0.0067 1/s on the Zwick Z600E testing machine.

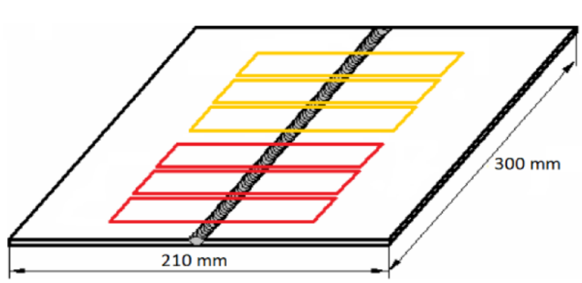

Fig. 1. Work piece after welding

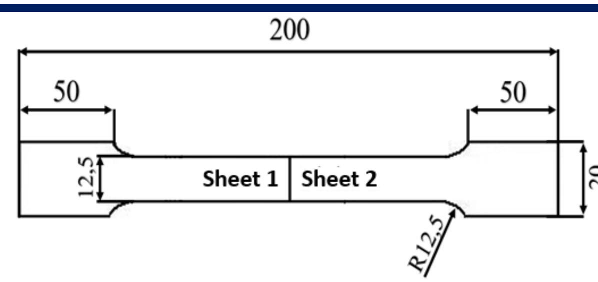

Fig. 2. Tensile test sample dimensions

Table 3. Experimental design used in welding process

Sample No	Arc Type & Voltage (V)	Wire Feed Speed (mm/sec)	WeldingSpeed (mm/sec)
Sample 1	Short - 25 V	6	11
Sample 2	Short - 25 V	6	13
Sample 3	Short - 25 V	6	15
Sample 4	Short - 25 V	7	11
Sample 5	Short - 25 V	7	13
Sample 6	Short - 25 V	7	15
Sample 7	Short - 25 V	8	11
Sample 8	Short - 25 V	8	13
Sample 9	Short - 25 V	8	15
Sample 10	Middle - 27 V	6	11
Sample 11	Middle - 27 V	6	13
Sample 12	Middle - 27 V	6	15
Sample 13	Middle - 27 V	7	11
Sample 14	Middle - 27 V	7	13
Sample 15	Middle - 27 V	7	15
Sample 16	Middle - 27 V	8	11
Sample 17	Middle - 27 V	8	13
Sample 18	Middle - 27 V	8	15
Sample 19	Long - 29 V	6	11
Sample 20	Long - 29 V	6	13
Sample 21	Long - 29 V	6	15
Sample 22	Long - 29 V	7	11
Sample 23	Long - 29 V	7	13
Sample 24	Long - 29 V	7	15
Sample 25	Long - 29 V	8	11
Sample 26	Long - 29 V	8	13
Sample 27	Long - 29 V	8	15

The gas arc welding parameters to be kept constant during the implementation of the created experimental work plan are given in Table 4.

Table 4. Values of the constant parameters

Elettrode Type	Electrode Diameter (mm)	Work piece Distance (mm)	Torch Angle (Degree)	Shield Gas Type	Flow rate of shield gas (lt/min)
SG2	1.2	18	20	%82 Ar %18 CO_2	12-14

The shape of the welding mouth of the materials to be joined by welding is shown in Figure 3. The larger the alpha angle, the higher the heat to which the materials to be welded will be exposed. Increasing the alpha angle causes grain coarsening and rupture from the base material instead of the weld joint. Although the alpha angle becomes smaller, the filler metal does not penetrate here during the welding process. In this study, the alpha angle is taken as 60°, which is the optimum value according to DIN 8551 [18].

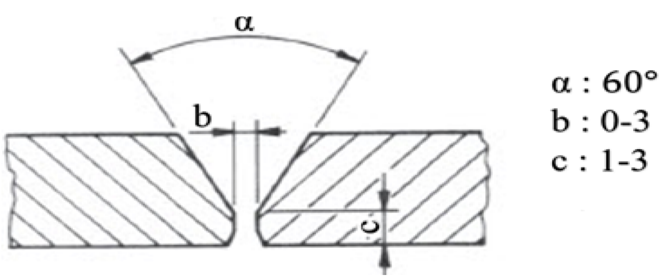

Fig. 3. Weld mouth according to DIN 8551

3. Result and Discussion

The tensile test was used to determine the effect of the welding parameters on the strength of the prepared welded specimens. Three replications were made for each experimental parameter. The results obtained were averaged. The ultimate strengths of S460MC and St52 materials obtained according to the test parameters are compared in Figure 4. According to the data obtained from the tensile test, the ultimate strengths of S460MC and St52 materials showed similar trend. When the tensile tests of the welded samples obtained from S460MC and St52 materials were examined, it was obtained that the highest tensile strength value was in the 5th sample. The ultimate strengths for St52 and S460MC materials were determined as 634.3 MPa and 622.7 MPa, respectively. It has been obtained that the welding parameters resulting the best mechanical properties were 25 V welding voltage, 7 mm/sec wire feed speed and 13 mm/sec welding speed for both St52 and S460MC materials. The tensile strengths of S460MC and St52 materials according to arc length were investigated. Comparison of average tensile strengths of St52 and S460MC materials according to arc length is given in Figure 5. The most suitable arc length value for both materials was determined as short (25 V). The average tensile strength values of the materials are found to decrease as the arc length value is increased.

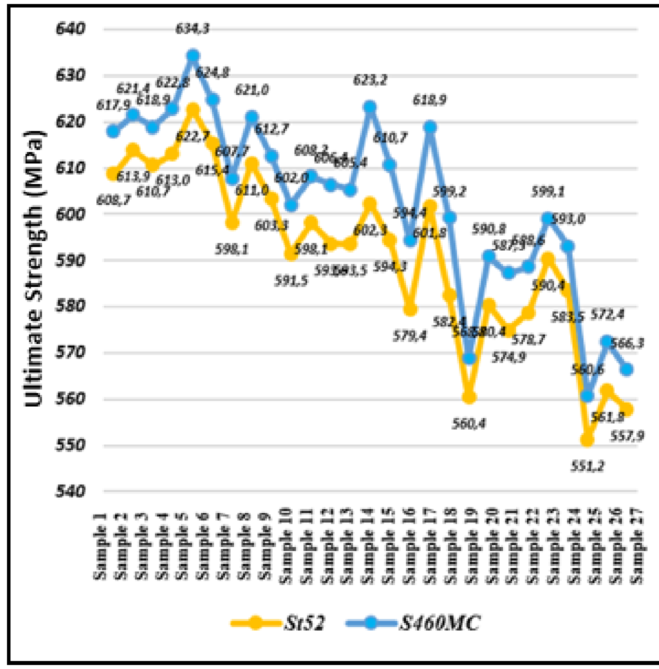

Fig. 4. Tensile test results of S460MC and St52 Material

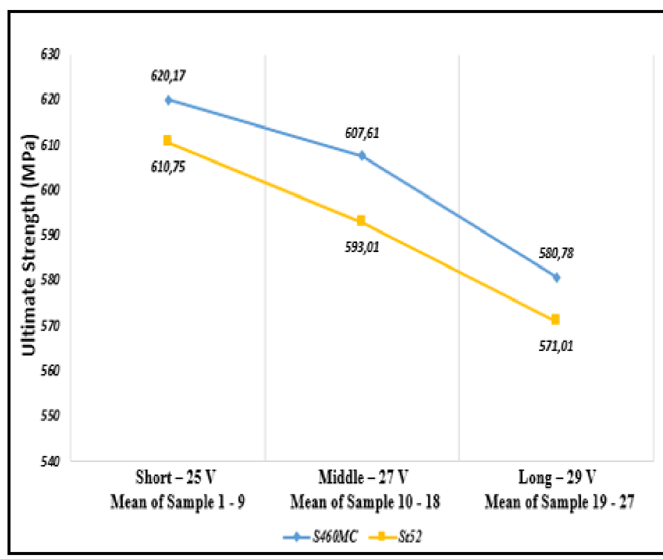

Fig. 5. Ultimate strength according to arc length of S460MC and St52 materials

The tensile strengths of S460MC and St52 materials were investigated according to wire feed speed parameters. The tensile strength values in different wire feed speed are given in Figure 6. After examining the average tensile strengths of the welded samples, it was found that 7 mm/sec was the best wire feeding speed, followed by 6 mm/sec and 8 mm/sec.

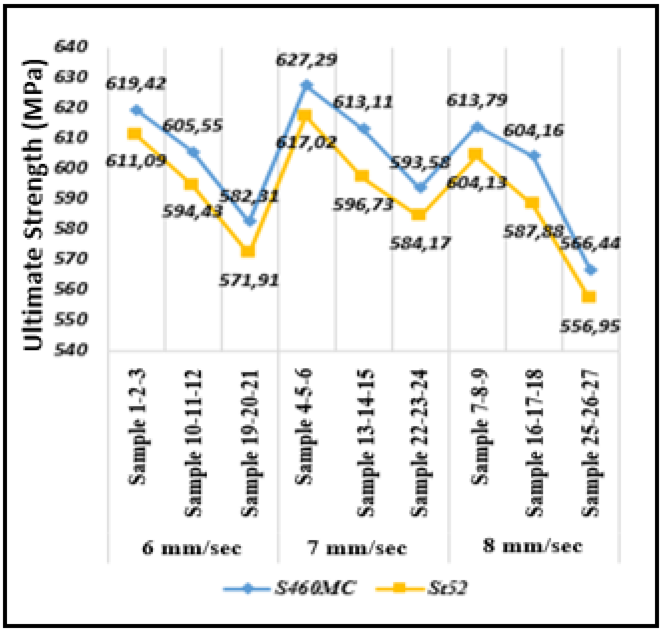

Fig. 6. Ultimate strength according to wire feed speed of S460MC and St52 materials

The tensile strength values in different welding speed are given in Figure 7. For the St52 material, the obtained results are close to each other at 15 mm/sec and 13 mm/sec welding speeds, and the optimum welding speed is 13 mm/sec. The S460MC material behaved similarly to the St52 material. It has been determined that the optimal feed rate for both materials is 13 mm/sec.

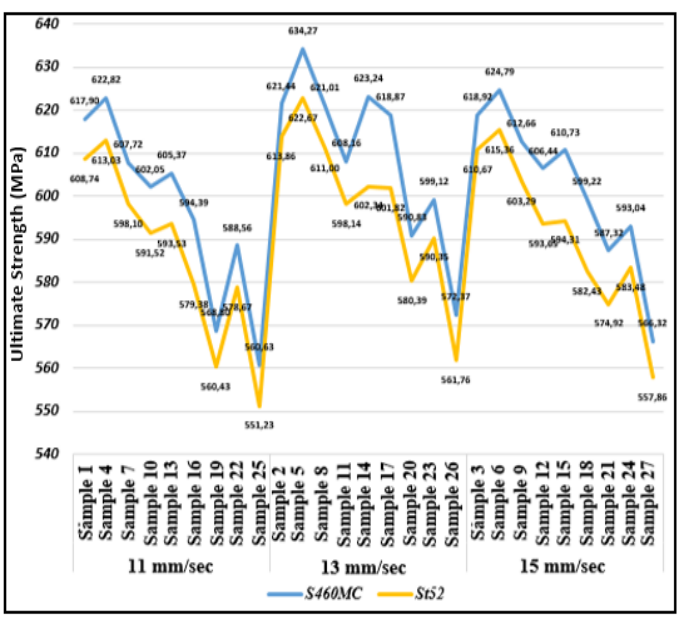

Fig 7. Ultimate strength according to welding speed of S460MC and St52 materials

4. Conclusions

S460MC and St52 steels sheets were joined by gas metal arc welding method. The effect of welding parameters on the tensile strength was investigated. The results obtained from the experimental studies can be summarized as follows :

- The optimum welding parameters providing the best mechanical properties were 25 V, 7 mm/sec and 13 mm/sec for the arc voltage, wire feed speed and welding speed, respectively.
- Similar effects were observed for both materials depending on the welding parameters.
- The higher strength values were obtained with short arc length.

Nomenclature

MAG	:	Metal active gas
HAZ	:	Heat affected zone
MIG	:	Metal inert gas

Conflict of Interest Statement

The authors declare that there is no conflict of interest in the study.

Credit Author Statement

Yiğit Okuroğulları: Conceptualization, Formal analysis, Validation
Oktay Çavuşoğlu: Data curation, Writing-original draft
Mümin Tutar: Methodology, Review & Editing
Hakan Aydın: Conceptualization, Supervision

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