A Study of the Effecting of Welding Process for Gas Metal arc Welding Between Ferritic Stainless Steel 1.4003 and Carbon Steel ss400

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Abstract

This research aimed to study the effect of gas metal arc welding parameters on 1.4003 ferritic stainless steel and SS400 carbon steel. There are three parameters for the experiment investigating the microstructure of the joint, Inspection of weld properties. It consists of a tensile test and a hardness test. The result is as follows. The gas metal arc welding could successfully produce the sound weld of 1.4003 ferritic stainless steel and SS400 carbon steel. An increase in welding speed affected to decrease in the tensile strength of the welds but did not affect to change the hardness of the welds. The study found that. The optimized welding parameter in this study that showed the ultimate tensile strength was welding wire ER308 LSI, welding current 120A, and welding speed 150 mm/min.

Keywords
Gas metal arc welding, Ferritic stainless steel 1.4003, Carbon steel SS400, Welding of dissimilar materials, Welding influence.

1. Introduction
In the current manufacturing industry, various metals are used as structural components to bring out each metal's strengths to meet users' needs. Welding is a popular method in the automobile manufacturing industry. However, it is quite challenging to join dissimilar materials. The two materials have different mechanical, physical, and chemical properties. As a result, the welding process is different. The bus chassis manufacturing industry uses various materials to increase efficiency and reduce production costs. Chassis design must consider the metal's anti-corrosion ability and the material's cost. It must take advantage of stainless steel in anti-corrosion and the lower cost of carbon steel used in the design of the Bus Chassis.

In general, in bus chassis production, most of the production process is carbon steel to carbon steel welding. However, the bus chassis manufacturing company in the case study chose to use ferritic stainless steel grade 1.4003 and carbon steel grade SS400 because the company in the case study did not study the parameters of welding processes between the two sheets of steel. Therefore, choosing the type of welding wire and adjusting the process parameters is not suitable for the nature of the job.

Based on the above problems, This research focuses on the welding process and the effect of welding factors between ferritic stainless steel and carbon steel by gas metal arc welding (Gas metal arc welding: GMAW), which will affect the properties of the workpiece. In addition, another purpose is to improve the bus chassis welding process of the case study company.

1.1 Objectives
- To study gas metal arc welding (GMAW) between ferritic stainless steel and carbon steel.
- To study the effects of gas metal arc welding on the mechanical properties of ferritic stainless steel and carbon steel weld.

2. Literature Review

In order to study gas metal arc welding parameters on 1.4003 ferritic stainless steel and SS400 carbon steel, the welding parameters such as welding wire, welding current, and welding speed influence the welding bead. In this study, it is necessary to test the workpiece to study its tensile strength and hardness and analyze the properties of the weld joints from reviewed and explored literature. It was found that the research was consistent with Sukchai et al.'s (2013) study about metal inert gas welding of carbon steel and stainless steel joint in the sugar production industry. This research aimed to weld a butt joint of SS400 carbon steel and AISI430 ferritic stainless steel using a Gas Metal Arc welding (GTAW) welding process and to study the effect of welding parameters on joint properties. The welded joint was prepared and examined for joint properties such as tensile strength (ASTM E8), hardness (ASTM E92), and microstructure. The study variation of the welding parameter, such as welding current, welding speed, and gas type, were optimized. The experimental results were concluded as follows. The optimized welding parameter that produced the tensile strength of 448 MPa was the welding current of 110A, the welding speed of 400 mm/min, and the mixed gas of 80%Ar + 20%CO_2.

An increase in the welding current and speed affected to increase or decrease of the tensile strength of the joint, respectively. An increase in the amount of a mixed gas type produced a better weld quality and increased the joint's tensile strength. Microstructure investigation of the welded joint showed a columnar grain in the weld metal and a coarse grain in the heat-affected zone (HAZ). The unknown hard precipitated phases were also found at the grain boundaries of the weld metal and HAZ. Moreover, this research corresponds with Amornsak (2014) research about gas metal arc welding of SS400 carbon and SUS304 stainless steel lap joint. This research aimed to study the effect of gas metal arc welding parameters on SS400 carbon steel and SUS304 stainless steel lap joint properties. The experimental work was carried out using a gas metal arc welding on a lap joint with various welding parameters. These parameters included a welding current of 80-120 A, 150-250 mm/min welding speed, and a 30-60 degree welding angle. The welded joints were mechanically prepared and investigated for tensile shear strength, macro and microstructure, and hardness of the welded joints.

3. Methods

Workpiece Preparation

Prepare the ferritic stainless steel grade 1.4003 and carbon steel grade SS400 by using a sheet metal shearing machine with a hydraulic system to the size 60x150x4mm.

Welding the workpiece

The workpiece is according to the parameters set and controls the welding speed. Therefore, it is feasible to bring the automatic gas-cutting metal machine to adapt to the welding process to control the travel speed. Moreover, in this step, the workpiece will be welded three times in each parameter, as shown in Table 1.

Table 1. Parameters of the experiment.

Welding parameters	Value
grade of welding wire	ER70S, ER308LSi
welding wire diameter (mm)	0.8
Arc current (A)	80,100,120
Voltage (V)	21
Travel speed (mm/min)	150, 210
Gas flow rate (l/min)	15
Travel Angle	15
Work Angle	90

Preparation of workpiece for Mechanical Testing

Preparing the workpiece for mechanical properties testing is bringing the welded workpiece and cutting it to the specified size to test the mechanical properties and metallurgical structure (Figure 1).

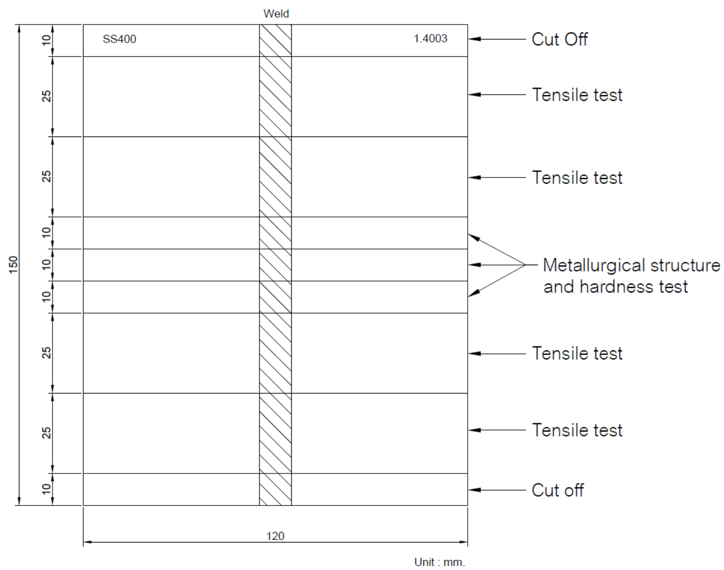


Figure 1. The workpiece has been cut for Testing.

After cutting the workpiece into two pieces, the first is used for tensile Testing (Figure 2). Furthermore, the second part is for metallurgical structure testing and hardness testing (Figure 3).

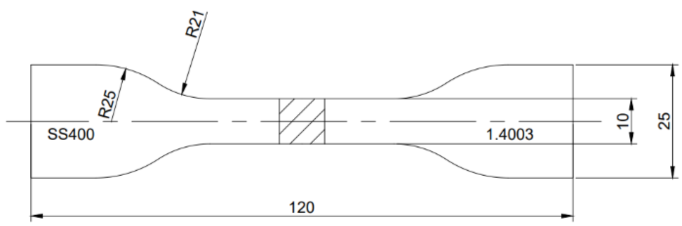


Figure 2. The pieces for tensile testing

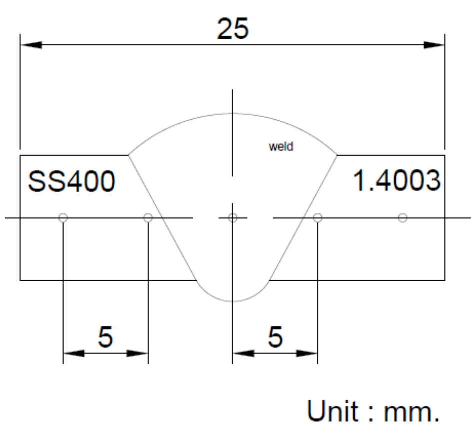


Figure 3. The pieces for the metallurgical structure and hardness test

The metallurgical structure testing

After welding the workpiece according to all parameters, the next step is to cut the workpiece into pieces measuring 25 mm long and 10 mm in width. Furthermore, bring the workpiece to metallographic hot mounting with a hot mounting press machine. And then, take the workpiece to surface preparation by polishing all seven sandpapers, which are nos. 150, 320, 400, 600, 800, 1000, and 1200, and polished with 0.3µm and 0.5µm alumina powder. Polish until clear and without scratches. Furthermore, take the workpieces to be etched with Nital acid and Hydrochloric acid. After that, the workpieces were examined through a microscope.

The tensile Testing

In the specimen tensile test, the tensile test was performed by a tensile testing machine with a pulling speed of 0.005 mm/s, and record the experimental results obtained from the tensile test. Which will consider recording the test results of the specimens. There are two types, which are the ultimate tensile strength, the percentage of elongation (%Elongation)

The hardness test

The microhardness test of the workpiece was carried out using a Vickers hardness tester, which will measure the hardness values in all five areas, which are 1. Base metal SS400 2. Heat Affected Zone of SS400 3. Weld bead area 4. Heat Affected Zone of Ferritic stainless steel 1.4003 5. Bass Ferritic stainless steel 1.4003

4. Data Collection

From the study of the influence of gas metal arc welding parameters, the welding bead data were collected at different parameters resulting in different welding bead appearances (Figure 4).In addition, the data on the weld bead characteristics of each carbon steel SS400 grade variable and ferritic stainless steel grade 1.4003 were collected.

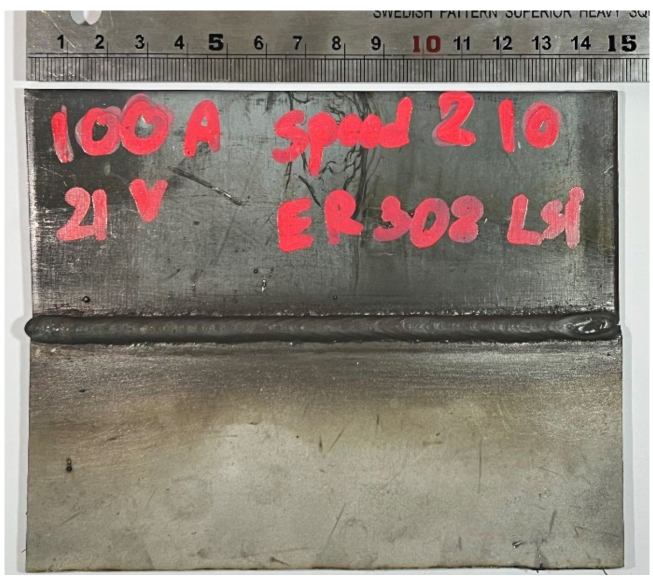


Figure 4. Example physical characteristics of the weld

Study the influence of gas metal arc welding parameters on the properties of the joint between carbon steel SS400 grade and ferritic stainless steel grade 1.4003 on mechanical properties affecting tensile and hardness values that can be measured. The experimental variables were: 1. Grade of welding wire ER70S, ER308LSi, 2. Welding speed 150, 210 mm/min, 3. 80, 100, and 120 A of welding current and welding experiments for all variables. Furthermore, bring the workpiece to test for the maximum tensile strength of each variable. Finally, the test piece's hardness shows the data collection results in Table 2 and Table 3.

Table 2. The table shows the average tensile test values.

Welding Parameter (GMAW)			Tensile Testing	
Wire	Speed (mm/min)	Amp	Ultimate (MPa)	Elongation (%)
ER70S	150	80	357.70	5.83
ER70S	150	100	343.70	3.33
ER70S	150	120	350.71	6.67
ER70S	210	80	320.90	0.00
ER70S	210	100	348.60	6.67
ER70S	210	120	342.00	7.50
ER308Lsi	150	80	330.00	0.00
ER308Lsi	150	100	355.59	7.50
ER308Lsi	150	120	359.09	7.50
ER308Lsi	210	80	319.89	0.00
ER308Lsi	210	100	343.01	6.67
ER308Lsi	210	120	344.41	7.50

Table 3. The table shows the average value of the hardness test.

Welding Parameter (GMAW)			Hardness Test (HV)				
Wire	Speed (mm/min)	Amp	Base SS400	HAZ (SS400)	Weld	HAZ (1.4003)	Base 1.4003
ER70S	150	80	105	116	242	223	172
ER70S	150	100	108	115	329	286	176
ER70S	150	120	109	111	271	247	176
ER70S	210	80	104	116	289	263	180
ER70S	210	100	106	113	275	273	169
ER70S	210	120	102	121	279	270	173
ER308Lsi	150	80	104	108	279	187	173
ER308Lsi	150	100	107	110	267	180	169
ER308Lsi	150	120	104	110	283	173	169
ER308Lsi	210	80	111	114	272	179	167
ER308Lsi	210	100	102	110	286	182	173
ER308Lsi	210	120	105	117	269	180	176

5. Results and Discussion

The workpiece will be analyzed in two parts: Firstly, mechanical properties, including tensile Testing and hardness, and secondly, the observation of macrostructure and microstructure to be taken into consideration the mechanical properties.

The welding structure of the specimen of Ferritic stainless steel 1.4003 and Carbon steel SS400 is considered in terms of macrostructure and microstructure. As a result, it was found that the metal texture of the weld and the metal texture of the workpiece had different characteristics could be explained as follows.

Macrostructure

When considering the macrostructure of the workpiece, it can be observed that there is a difference between the weld metal and the workpiece metal due to the current arc variable that affects the characteristics of the penetration depth of the weld bead. The macrostructure test found that ER308LSi wire, arc current 120 A, travel speed 150 mm/min had complete melting and deep penetration between workpieces. It was found that ER308LSi wire, arc current 80 A, travel speed 210 mm/min had incomplete melting and deep penetration between workpieces. The welding line does not penetrate deeply, affecting the tensile strength of the workpiece.

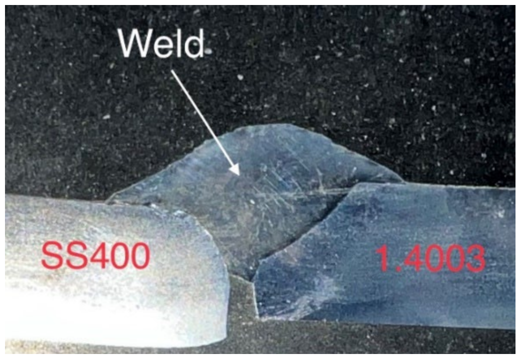


Figure 5. Macrostructure of incomplete Weld.

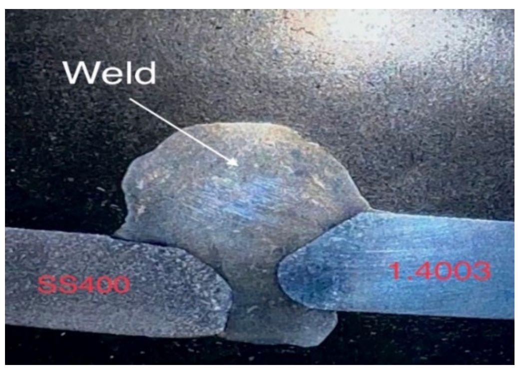
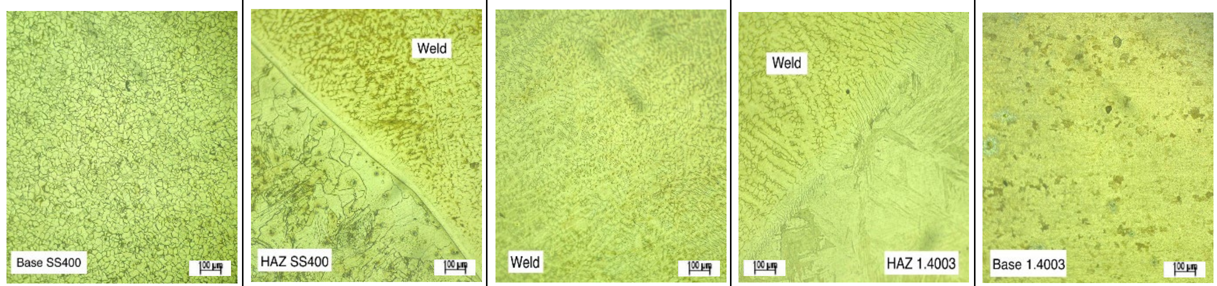


Figure 6. Macrostructure of complete Weld.

Microstructure

From Testing to measure the microhardness test of the workpiece using a Vickers hardness tester, which will measure the hardness values in all five areas, which are 1. Base metal SS400 2. Heat Affected Zone of SS400 3. Weld bead area 4. Heat Affected Zone of Ferritic stainless steel 1.4003 5. Bass Ferritic stainless steel 1.4003



Base SS400	HAZ SS400	Weld	HAZ 1.4003	Base 1.4003

Figure 7. Microstructure at an arc current 120 A and travel speed 150 mm/min

The microstructural observations of the joint formed by welding carbon steel SS400 and ferritic stainless steel 1.4003 revealed the columnar grain arrangement (Figure 7). The structure is divided into two distinct areas, with many black lines and white areas. In the Heat Affected Zone of SS400 and the weld, it was found that there was less melting in the fusion line area of carbon steel. This could be observed from the interface and Heat Affected Zone areas, which are characterized by the grain size structure not being uniform. Patternless alignment and has different structural characteristics from the weld area. In the Heat Affected Zone of ferritic stainless steel 1.4003 and weld, it was found that the fusion line has a longitudinal grain structure similar to that of columnar grains, which are predominantly formed at the fusion line. The microstructure at the Heat Affected Zone is similar to the structure of the welding zone, which has alternating white and gray areas. Furthermore, it was observed that the base metal SS400's main structural component was ferrite and that Base 1.4003's main structural component was predominantly ferrite with sporadic carbides.

Tensile strength

When analyzing the results from the data collection average tensile test values in Table 1, it was found that the experiment showed that the welding current variable affected the properties of the weld line by analyzing the tensile strength of all test specimens under specified variable conditions and comparing the obtained values with the differences in tensile strength. It can be shown in Figure 8.

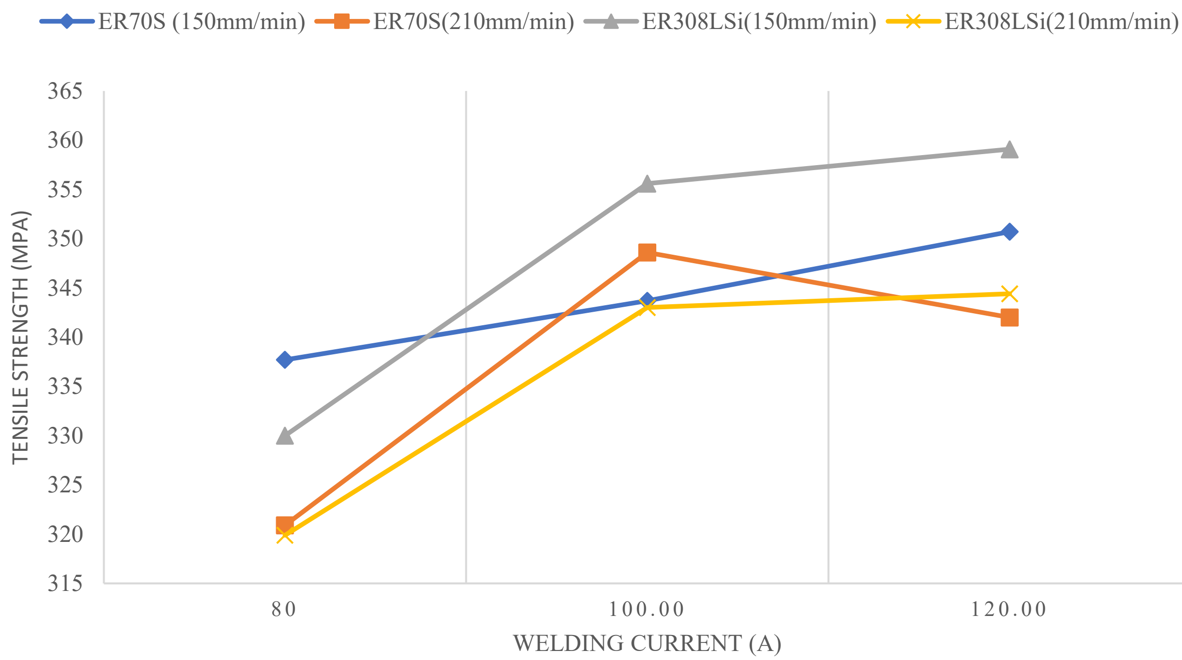


Figure 8. Comparison of tensile strength from current factor at current 80, 100, 120 A

A comparison of tensile strength from current factor 80 – 120 A found that welding current and welding speed affect the tensile strength of test specimens at ER308LSi wire grade. At 120 A welding current, welding speed 150 mm/min gives the highest tensile strength at 359.09 MPa and the lowest tensile strength at 319.89 MPa at ER308LSi wire grade at 80 A welding current, welding speed 150 mm/min.

When taking the workpiece to consider the breakdown point (Figure 9), It was found that it was consistent with the tensile test result, as shown in Table 1. therefore, at the breaking point of the workpiece at an arc current of 80 A, the workpiece was broken at the edge of the weld bead. At the arc current of 100 A and 120 A, the workpiece was broken at The area of SS400 steel. That means the weld bead can take more tensile strength than SS400 steel.

Figure 9. The breaking point of the workpiece

Hardness Test

To analyze the hardness measurement test results, Collecting the hardness measurement data from Table 2. shows that the hardness of the weld line depends on the factors of welding wire, current and welding speed. For example, the weld that welded with ER70S grade electrode at the welding current of 100 A and a travel speed of 150 mm/min gave the highest weld hardness value of 329 HV. Furthermore, at an arc current of 80 A, a travel speed of 150 mm/min will give the lowest weld hardness of 242 HV, as shown in Figure 10.

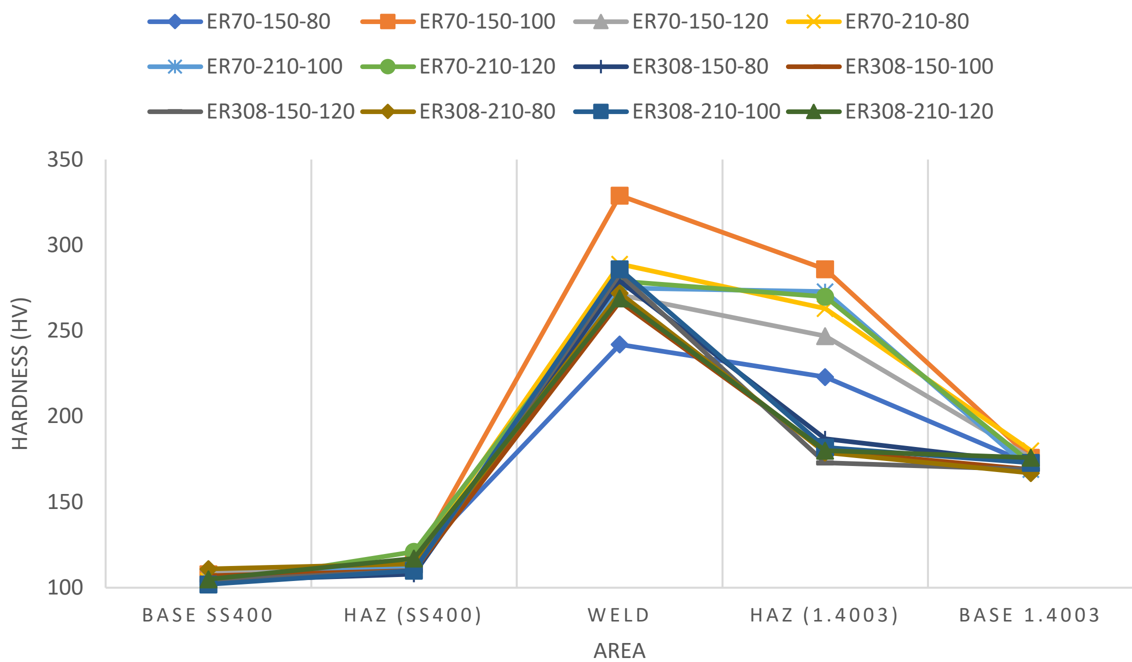


Figure 10. Comparison of Hardness Test from current factor at current 80, 100, 120 A

From the test, measure the hardness of the workpiece in all five areas, which are 1. Base metal SS400 2. Heat Affected Zone of SS400 3. Weld bead area 4. Heat Affected Zone of Ferritic stainless steel 1.4003 5. Bass Ferritic stainless steel 1.4003. The hardness value was found to be the highest in the weld area. Compared with the hardness of each area, it was found that the Heat Affected Zone of the Ferritic stainless steel 1.4003 workpiece had a hardness almost similar to the weld area. In contrast, the Heat Affected Zone of Carbon steel SS400 had less hardness than the weld bead, and the Heat Affected area zone of the workpiece Ferritic stainless steel 1.4003.

Proposed Improvements

The study of the influence of gas metal arc welding process parameters between stainless steel grade 1.4003 and carbon steel grade SS400 can be improved as follows. In welding, for additional comparison of mechanical properties, such as changing other wire grades. Moreover, it should study other effects to provide a more comprehensive analysis of results to choose which to use.

6. Conclusion

The experimental results can be analyzed to show that the most appropriate arc current was 120 A, and the welding speed was 150 mm/min with ER308LSi grade wire, which gave the highest tensile strength of 359.09 MPa. The study found that such welding variables affected the melting and metallurgical transfer between the welding wire and the workpiece due to the appropriate arcing of the test piece and the optimum melting rate of the wire. From the tensile test, it was found that most of the test pieces broke down at the welding line at 80 A current. Therefore, the welding current at 80 A was not suitable for use. On the other hand, because the welding wire's melting rate is inadequate, the welding's penetration is less. Furthermore, at arc currents of 100 A and 120 A, the test piece's tear marks are on the side of SS400 steel, making it suitable for use.

The hardness test revealed that the welding areas of SS400 and ferritic stainless steel 1.4003 had a higher hardness than the Heat Affected Zone on both sides. And from the results of the microstructural analysis of the weld area. The structure of the workpiece that gives it the highest tensile strength is ferrite. The hardening characteristic is columnar, which tends towards the middle of the weld under heat, causing the structure to resemble dendrites.

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Biographies

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