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THE EFFECT OF SHIELDING GAS ON SURFACE DEFECTS AND MECHANICAL PROPERTIES OF MATERIALS AFTER THE GMAW WELDING

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Abstrak— Penelitian ini bertujuan untuk menganalisis kekuatan dan hasil sambungan las dengan melakukan pengujian non destruktif dan destruktif dengan menggunakan gas pelindung CO_2 dan argon. Jenis pengelasan yang digunakan adalah las busur logam gas dengan material baja SS400. Setelah dilakukan pengelasan, material diuji menggunakan uji penetran cair, porositas, tarik, dan tekuk. Hasilnya gas pelindung CO_2 cenderung berbentuk cembung dan lebar, sedangkan hasil pengelasan dari gas argon cenderung berbentuk kecil dan datar. Pada kedua gas pelindung, terdapat cacat pada undercut, kurangnya fusi, dan percikan setelah uji penetran cair. Hasil uji porositas terdapat bintik-bintik berbentuk lingkaran dan garis-garis tidak beraturan yang berlubang. Nilai kuat tarik rata-rata yang diperoleh dari gas pelindung argon sebesar 255,76 MPa, dan gas pelindung CO_2 menghasilkan nilai rata-rata sebesar 214,03 MPa. Kekuatan lentur material dengan gas pelindung argon diperoleh nilai rata-rata sebesar 729,00 MPa dan gas pelindung gas CO_2 nilai rata-rata sebesar 611,99 MPa.

Kata Kunci— gas metal arc welding; shielding gas; CO_2; Argon

Abstract*— This research aims to analyse the strength and results of welded joints by testing non-destructive and destructive tests using CO_2 and argon shielding gases. The type of welding used was gas metal arc welding with SS400 steel material. After welding, the material was tested using liquid penetrant, porosity, tensile, and bending tests. The results were that CO_2 shielding gas tended to have a convex and wide shape, while the welding results from argon gas tended to have a small and flat shape. In both shielding gases, there were defects in undercuts, lack of fusion, and spatter after the liquid penetrant test. The porosity test results have circular spots and irregular lines with holes. The average tensile strength value obtained from argon shielding gas was 255.761 MPa, and CO2 shielding gas produced an average value of 219.671 MPa. The bending strength of the material with argon shielding gas obtained an average value of 729.00 MPa and CO_2 gas shielding an average value of 611.99 MPa.*

Keywords— gas metal arc welding; shielding gas; CO_2; Argon

INTRODUCTION

Welding is a technique of joining two metals by heating or melting, using an electric arc or electric current to melt the metals being joined. There are various types of welding, such as SMAW (Shielded Metal Arc Welding), FCAW (Flux Core Arc Welding), GMAW (Gas Metal Arc Welding), and GTAW (Gas Tungsten Arc Welding). This type of welding was commonly used in GMAW welding (Arsyad et al., 2019). The GMAW uses argon and CO_2 gas as shielding gases to prevent arcing and metal melting (Parekke, 2017). Shielding gas is an essential tool in GMAW welding. Increasing the shielding gas flow rate will increase the penetration depth and pressure, thereby improving the welding results. Increasing this shielding gas affects material strength and welding results (Firmansyah, 2017). In general, the GMAW uses CO_2 gas as a shielding gas, but there is another shielding gas that can be used, namely argon gas (Anzharie et al., 2020).

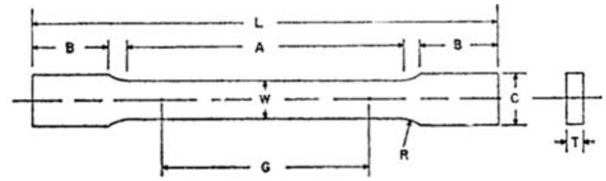
Fakri & Juhan, 2019 studied the analysis of the effect of GMAW welding current on the toughness of AISI 1050 steel connections. It uses CO_2 gas as a medium to prepare the weld metal and protect it from the influence of the weld metal with a V butt joint at an angle of 70°. The current variations in this welding process are 100, 120, and 140 Amperes. The tests show that the highest shock strength (impact) at a current of 100 Ampere produces a toughness value of 2.36 joules/mm². Meanwhile, the lowest impact test results at a current of 120 Ampere produced a toughness value of 2.02 joules/mm². The results of the fracture form after the impact testing process show that the test object at a current of 100 Ampere experienced a ductile fracture, and mixed fractures occurred at currents of 120 and 140 Amperes.

Putra et al., 2016 studied the effect of current and temperature on the tensile strength of aluminum 5083 in the GMAW with the double V butt joint welding method at an angle of 60°. The current for tensile and bending tests uses a current of 130, 150, 170, and 200 amperes, and temperature changes of 20°C, 0°C, and -20°C are used for bending tests. From the tensile test results, the highest tensile strength was 193.28 N/mm2, and the highest strain was 0.86%, namely at a current of 130 Amp, and the impact test results showed the highest strength was 0.17 J/mm^2 at a current of 130 Amp with a temperature of 20ºC. So, GMAW welding on 5083 aluminum material in the optimal or best condition provides a large tensile strength at a current of 130 amps. Meanwhile, for impact testing, the optimal and best condition is taken to provide the highest impact strength produced at a temperature of 20ºC with a current strength of 130 amps of 0.17 J/mm^2

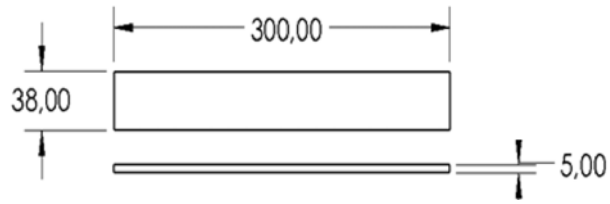
In the current study, the analysis carried out of the strength and results of welded joints using NDT (Non-Destructive Test) testing by the liquid penetrant test and observing porosity in the weld results as well as DT (Destructive Test) testing by the tensile test and bending test for determine the quality of welding results from the comparison of CO_2 shielding gas and argon gas in GMAW MIG (Metal Inert Gas) welding of SS400 (Structural Steel 400) steel material.

METODE

This research uses SS400 steel material with a length of 300 mm, width of 150 mm, and material thickness of 5 mm. The type of joint used is a single V butt joint. The initial preparation before welding is to clean the material from grease, oil, dust, and other adhering dirt. The GMAW was carried out indoors using DCRP (Direct Current Reverse Polarity) current polarity with voltage and current of 20 volts and 100 amperes, respectively. The shielding gas varies between argon and CO_2, with a 10-15 lpm flow rate. The electrode wire used was ER70S-6, with a diameter of 1.0 mm. Various tests were carried out to determine the quality of the welding results, including a liquid penetrant test to detect defects in the weld metal area, such as the weld beads' length, thickness, and width. The next stage was making specimens for tensile tests and bending tests. Each test uses three specimens of each shielding gas. Before the tensile test, this specimen was subjected to a porosity test to determine surface defects in the weld metal, including porosity and line defects.



(A)



(B)

Figure 1. (A) Tensile test specimen design (ASTM E8, 2010), (B) Bending test specimen design (ASME Section IX, 2019)

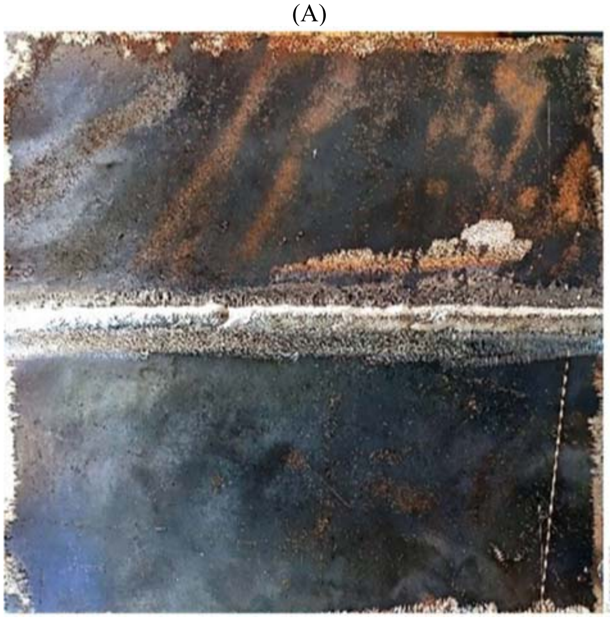
Mechanical properties testing was conducted to assess the effect of variations in shielding gas on the tensile and bending strengths of all welding results. Tensile testing was carried out according to ASTM E8 (American Standard Testing and Material) standards with the shape and size of the specimen as in Figure 1(A). The standard specimen used was sheet type 12.5 mm, gauge length (G) 50 mm, width (W) 12.5 mm and thickness (T) 5 mm, fillet radius (R) 12.5 mm and length Overall (L) 200 mm, length of the reduced section (A) is 57 mm and length of grip section (B) is 50 mm and width of grip section (C) is 20 mm. Bending testing uses ASME BVPC Section IX (American Society of Mechanical Engineers Boiler and Pressure Vessel Code) standards with the shape and size of the specimen shown in Figure 1(B). mm^2

RESULTS AND DISCUSSION

Visual observation

Visual observation results from welding with variations in shielding gas from CO_2 gas and argon gas carried out per predetermined standard welding procedures are shown in Figure 2. The visual observation results show that the shielding gas with argon gas has a smaller shape than CO_2, as in Figure 2(A), because the physical characteristics of the argon shielding arc tend to be small and flat. The CO_2 shielding gas tends to be convex and wide, as in Figure 2(B). It is caused by the physical characteristics of the CO_2 shielding arc and the weld puddle, resulting in a convex bead shape. Therefore, the physical characteristics of the arc and the shielding gas will affect the weld result.

(A)



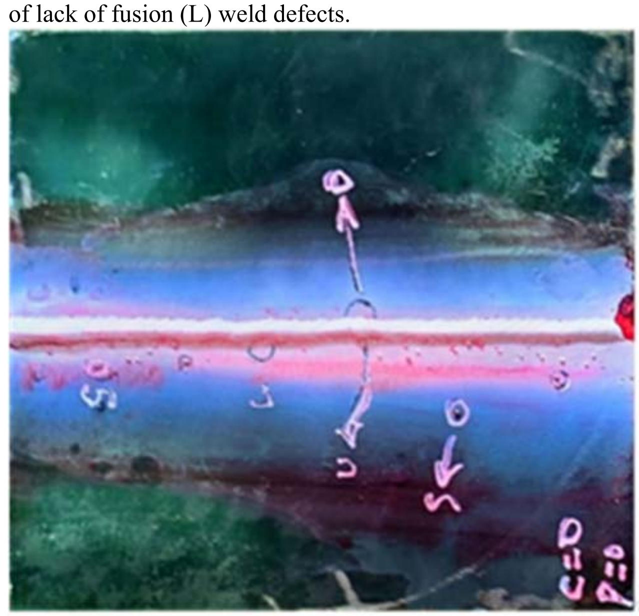
(B)

Figure 2. Visual observation of: (A) The argon gas, (B) The CO2 gas

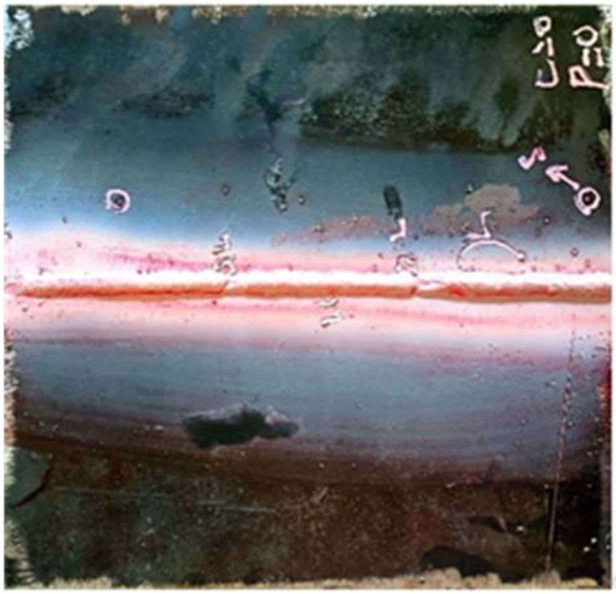
Liquid penetrant test

The liquid penetrant test is a simple method that sprays liquid penetrant on the welding results to determine open surface defects in the weld area. Defects from the results of this test include undercuts, lack of fusion, and spatter. Undercut weld defects are caused by the welding current and welding speed being too high, resulting in melting. The size of the defects obtained ranged from 7-9 mm in each shielding gas. The lack of fusion welding defects is caused by the welding current being too low, but the welding speed is too high, so the weld metal does not entirely fuse with the base metal or other metal layers. The size of the lack of fusion defect in the data obtained ranges from 5-11 mm in each shielding gas. Spatter welding defects are caused by the welding current being unstable and too high, causing sparks in the weld area. The size of the type of spatter defect obtained ranges from 1-2 mm in each shielding gas (Pratama et al., 2020). The test results can be seen in Figure 3.

Figures 3(A) and 3(B) are the results of the liquid penetrant test, which shows the appearance of weld defects in the weld area marked with letter symbols. The letter symbols listed are the letters S (spatter), U (undercut), P (porosity), C (crack), and L (lack of fusion). There are several differences regarding the weld defects recorded, where the weld defects in Figure 3(A) show the many types of spatter (S) and undercut (U) weld defects. In contrast, Figure 3(B) shows the many kinds of lack of fusion (L) weld defects.



(A)



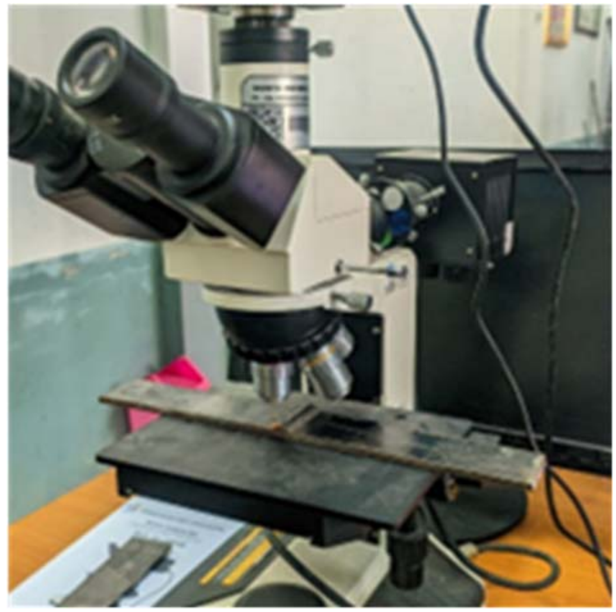
(B)

Figure 3. Liquid penetrant test: (A) The argon gas, (B) The CO_2 gas

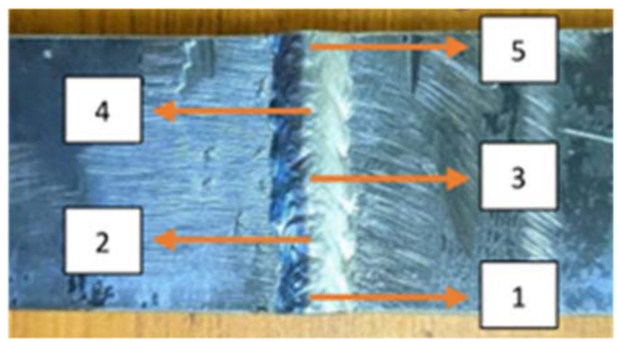
From the results of liquid penetrant testing with variations of GMAW shielding gas, it can be seen that the characteristics of CO_2 shielding gas tend to produce a less stable arc and more spatter, resulting in other welding defects such as undercuts, lack of fusion, and more spatter compared to argon shielding gas. Additionally, more and more weld defects require post-weld cleanup, leading to undesirable downtime. The characteristics of argon shielding gas produce a stable arc, provide consistent weld quality and appearance, and also give the operator reasonable weld pool control, as well as create a narrow penetration profile that makes it ideal for fillet and butt welds. Because argon produces less spatter, it can also help minimize downtime associated with post-weld cleanup.

Porosity test

Porosity observations in the weld results were carried out on specimens with different variations of shielding gas. Specimen placement and image recording points are shown in Figures 4(A) and (B), respectively. The porosity testing process on this microscope was carried out with the magnification lens of the microscope used 20x with an automatic color filter (see Figure 4(A) and captured at five different points from point 1 to point 5 as in Figure 4(B). When taking photos, measuring the distance between points was done by dividing the 38 mm width of the specimen into five points. So, every 7.6 mm at each point to see the porosity test results. The distance between the specimen and the microscope lens depends on the height of the weld results.



(A)



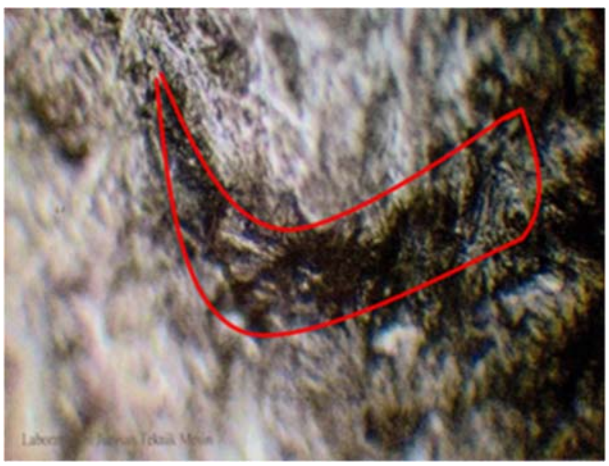
(B)

Figure 4. Porosity test: (A) Specimen placement, (B) Porosity test point

The results of observing weld porosity can be seen in Figure 5. Figures 5(A) and (B) with argon shielding gas show the results of weld porosity with a small round shape and a tick-like shape, where this porosity is included in the light group because light severity generally does not have a significant impact on the strength and durability of the weld. Figures 5(C) and (D) with CO_2 shielding gas show the results of weld porosity with a small round shape and irregular lines, where this porosity is included in the medium group because the porosity has quite a large number of visible pores and is concentrated in several areas. It can reduce the strength and durability of the weld.

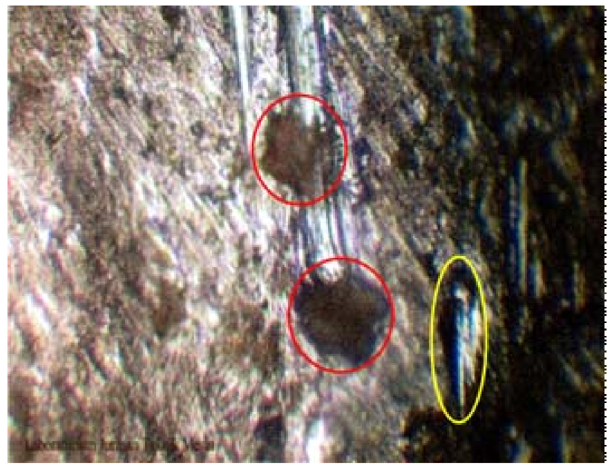
By looking at the weld porosity in Figure 5, it can be reported that the shape of the porosity greatly influences the weld area. The image shows the pores resulting from welding with black spots with holes (red line) and irregular striped holes (yellow line). One of the causes of weld porosity is the initial air bubbles during the welding process up to the weld boundary. The form of porosity indicates that the weld metal has small holes and uneven lines, which tend to cover the surface area of the weld. However, this weld metal is still considered safe.

(A)



(B)

(C)



(D)

Figure 5. Welding porosity: (A) The argon gas at point 1, (B) Argon gas at point 3, (C) The CO_2 gas at point 1, (D) The CO_2 gas at point 3

Tensile test

Tensile testing is a test in which a tensile force or tension is applied to a material intended to determine the strength of the material being tested (Mawahib et al., 2017). Table 1 displays the tensile stress results based on various test results. In the variation of shielding gas used in the tensile test, it was seen that the difference in results for the highest tensile test value was in the one argon gas specimen and the three CO_2 gas specimens where the resulting values were 286.70 MPa and 276.84 MPa. This average value differs from the shielding gases, namely argon gas and CO_2 gas, which have an average tensile stress value of 255.76 MPa and 214.03 MPa. It can be concluded that there is a higher difference in average tensile strength between argon shielding gas compared to CO_2 shielding gas. Several factors most likely cause this difference in tensile strength. One is that the shielding gas's composition can affect the weld metal's properties, including its tensile strength.

Table 1
Tensile test data

Shielding Gas	Specimen	Thickness (mm)	Width (mm)	Area (mm^2)	Max Load (N)	Max Point Stress (Mpa)
Argon	1	5	12.5	62.5	17918.9	286.70
	2	5	12.5	62.5	15389.9	246.24
	3	5	12.5	62.5	14646.3	234.34
				Average	**15985.03**	**255.76**
CO_2	1	5	12.5	62.5	8544.5	136.71
	2	5	12.5	62.5	14283.4	228.53
	3	5	12.5	62.5	17302.8	276.84
				Average	**13376.9**	**214.03**

Bending Test

A bending test is a method for carrying out bending tests that apply a compressive force to the test object during testing. Data from Tables 2 and 3 show the bending stress of various shielding gases. The highest bending test values were found in specimens one and three from argon gas, producing values of 800.00 MPa and 729.00 MPa. On the other hand, the specimen from CO_2 gas produced the highest value of 682.91 MPa. It can be seen that the average bending stress value for argon shielding gas is higher compared to CO_2 shielding gas, where the values are 729.00 MPa and 611.99 MPa, and the bending stress value of argon gas produces a more consistent value than CO_2 gas. One of the factors that causes differences in bending stress values is the nature of the shielding gas used. Argon shielding gas has better inert properties compared to CO_2 shielding gas. Argon gas can protect the metal from oxidation and contamination during welding. The data shows that argon shielding gas produces higher bending stress values than CO_2 shielding gas. This means that argon gas is more suitable for welding applications that require high strength and durability.

Table 2
Argon gas bending test data

Gas Argon	Max Force (kgf)	Tensile Strength (Mpa)	Yield Force (kgf)	Yield Stress (Mpa)	Displacement (mm)	Elongation (%)
1	783,14	1024,67	611,89	800,00	23,90	10,04
2	752,79	984,96	509,67	666,86	42,46	17,84
3	802,64	1050,19	549,93	719,53	45,27	19,02
Average	**779,52**	**1019,94**	**557,16**	**729,00**	**37,21**	**15,63**

Table 3
CO_2 gas bending test data

CO_2 gas	Max Force (kgf)	Tensile Strength (Mpa)	Yield Force (kgf)	Yield Stress (Mpa)	Displacement (mm)	Elongation (%)
1	517,61	677,25	405,49	530,55	14,39	6,05
2	659,54	862,95	475,78	622,52	16,74	7,03
3	743,20	972,41	521,94	682,91	21,27	8,94
Average	**640,12**	**837,54**	**467,74**	**611,99**	**17,47**	**7,34**

SUMMARY REMARKS

After analyzing variations in the GMAW shielding gas using NDT and DT testing on SS400 steel, several things can be summarized as follows:

a. The physical characteristics of the CO_2 shielding arc and the weld puddle produced in the welding process cause CO2 shielding gas to tend to have a convex and wide shape. In contrast, argon gas has the physical characteristics of a shielded arc, which produces a flat surface and good reinforcement but reduces excess welding.
b. The penetrant liquid test results show that the characteristics of the CO_2 shielding gas produce a less stable arc and more spatter compared to the characteristics of the argon shielding gas, which produces a stable arc and a consistent weld appearance.
c. The porosity test found that argon shielding gas has a surface structure with perforated lines and pores, which tend to be evenly distributed throughout the weld area. In contrast, the perforated lines and pores in CO_2 shielding gas tend to be concentrated in several areas.
d. The tensile test results show that the highest values for argon and CO_2 gases are 286.70 MPa and 276.84 MPa, respectively. This indicates that the SS400 steel material that has undergone the welding process has different brittle properties and strengths. The bending strength of argon gas is 557.16 kgf, than CO_2 shielding gas, with an average of 467.74 kgf.

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