The Effect of Shielding Gas Consumption and Electric Current on the Tensile Strength of SGC440 in Gas Metal Arc Welding (GMAW)

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Abstract - **Structural galvanized steel SGC440, known for its high tensile strength, is commonly used in the manufacturing of vehicle bodies, especially for cars and buses. The Gas Metal Arc Welding (GMAW) method is considered most suitable for connecting SGC440 plates. Despite its effectiveness, GMAW welding often faces challenges such as bending deformation and excessive burning, which can lead to damage in the welded areas. The use of shielding gas and the electric current need to be adjusted to achieve optimal joint quality. Therefore, an investigation into the parameters of shielding gas flow rate and the magnitude of the electric current is necessary to determine the quality of the joints. This study aims to determine the tensile strength of SGC 440 steel resulting from GMAW welding with variations in shielding gas consumption and the electric current used. Tensile strength testing of the samples was carried out following the JIS Z 2201 standard. The welding results indicate that variations in the shielding gas flow rate and the magnitude of the electric current affect the tensile strength. Additionally, microstructure observations show differences in the material's phase structure due to the influence of the electric current magnitude and shielding gas consumption.**

Keywords: Welding, Tensile, Microstructure, Shielding gas, Electric current.

I. INTRODUCTION

Structural Galvanized Cold (SGC) 440 Steel is a high-tensile-strength steel commonly applied in vehicle body structures such as cars and buses. Its high zinc content gives it an advantage in terms of corrosion resistance[1]. The process of joining SGC 440 steel through welding is frequently employed in the production of desired vehicle units in the manufacturing industry. Despite its corrosion resistance and superior mechanical properties, a challenge arises as not all types of welding can be applied to connect this type of steel. When the metal is heated during welding, corrosion easily occurs. The addition of shielding gases such as carbon dioxide is required to prevent corrosion by inhibiting the entry of oxygen into the weld metal [2]. Considering the size of the welded product and the need for time and cost efficiency in production, it can be concluded that the most suitable welding method is Gas Metal Arc Welding (GMAW).

Gas Metal Arc Welding (GMAW) produces a flame originating from the electric arc used to melt the base metal and filler metal. The oxidizing shielding gas employs inert gases such as Argon or more economical non-inert gases like CO_2. The GMAW welding process offers several advantages, including high efficiency, minimal production of slag, and welded joints with good toughness and elasticity. The use of shielding gas, specifically carbon dioxide, in GMAW welding can impact the welding outcomes[3]. Additionally, the magnitude of the electric current used needs to be adjusted according to the flow rate of the shielding gas to achieve optimal joint quality[4,5]. Therefore, an investigation into the parameters of shielding gas flow rate and the magnitude of the electric current is essential to determine the quality of the joints in SGC 440 steel.

Several studies related to the use of shielding gas consumption and electric current in the welding process have been analyzed. The magnitude of the electric current is adjusted based on the thickness of the welded metal. The impact of different welding currents on temperature, velocity, and pressure fields on the workpiece surface results in increased maximum values of arc temperature, arc plasma velocity, and arc pressure on the workpiece surface with an increase in welding current[6]. Consumption and types of shielding gases were analyzed with a welding current of 300A, and the results showed that the altered arc radiation due to different shielding gases had an effect on the heat input into the shielding gas nozzle and, ultimately, into the torch. Additionally, for the same shielding gas, this influence largely correlates with welding voltage. There is an influence on the change in microstructure in the welded metal due to the welding process with different electric currents [7]. However, there is limited analysis on the GMAW welding of metal with

SGC 440 material, despite its widespread use in the automotive industry.

This study aims to investigate the influence of CO_2 shielding gas consumption and the magnitude of the electric current used in Gas Metal Arc Welding (GMAW) using SGC 440 material. Variations in current strength and shielding gas flow rate are conducted to determine the optimal variations of both parameters. Tensile testing and microstructure observations are performed to assess the changes resulting from the given welding parameters.

II. METHOD

2.1 Preparation of Samples

The material used was a metal plate of SGC 440 type, which was then welded using Gas Metal Arc Welding (GMAW) and carbon dioxide as the shielding gas. The welding parameters are indicated in Table 1, while the welding machine is shown in Figure 1. After the welding process, the samples were formed into tensile test specimens following JIS Z 2201 NO.5 standards. The specimen formation was carried out using a 50 Ton capacity press machine equipped with a cutting tool blade. The formed samples are illustrated in Figure 2. The dimensions of the SGC440 steel used had a thickness of 1.6 mm, and the sample dimensions are shown in Figure 2. The Chemical Composition of SGC440 Steel: JIS G 3302, as used, is presented in Table 2.

Figure 1: Gas Metal Arc Welding (GMAW) Machine

Table 1: Welding Parameters for the Samples

Specimen names	CO$_2$ Flow (Liter/ Minute)	Electric Current (Ampere)
Specimen 1	-	-
Specimen 2	10	160
Specimen 3	10	180
Specimen 4	10	200
Specimen 5	5	180
Specimen 6	10	180
Specimen 7	15	180

Table 2: Composition of the Samples

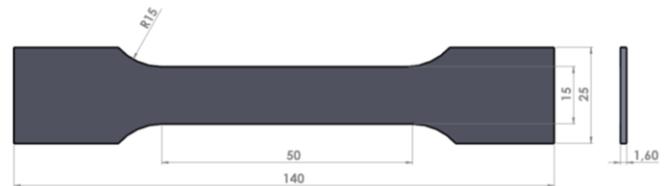| No	Material Penyusun	Persentase (%)
1	Karbon *(C)*	0.35
2	Mangan *(Mn)*	2
3	Fosfor *(P)*	0,040
4	Sulfur *(S)*	0,040
5.	Fe	Balance

Figure 2: Dimensions of Tensile Test Specimen

2.2 Testing of Samples

After the welding process, Tensile testing was conducted using a 50-ton capacity Hung Ta tensile testing machine, as shown in Figure 3. The testing process in this study was carried out at the QA (Quality Assurance) Laboratory of ISTW company Semarang and the Mechanical Engineering Laboratory of Muhammadiyah University. The specimen was clamped at both ends in the grip jaws, and then pulled in different directions (uniaxial).

Figure 3: Tensile testing machine

Figure 4: IMM 902 microscope

The Tensile testing results were recorded by the computer. The specimen with the highest and lowest tensile test results was used as a reference for creating microstructure

specimens. Microstructure observations were performed using the IMM 902 microscope with a lens magnification of 200x (Figure 4). The observed structural changes in the welded material are divided into three parts: Base Metal, HAZ (Heat Affected Zone), and Weld Metal.

III. RESULTS AND DISCUSSIONS

Before analyzing the effects of Gas Metal Arc Welding (GMAW) welding parameters, non-welded samples served as a reference for comparing the tensile strength analysis of welded samples. The tensile testing results for non-welded samples of the base material SGC 440 show a tensile strength value of 495.5 N/mm². With the same shielding gas consumption of 10 L/minute and different electric current settings, variations in tensile strength are observed, as shown in Figure 5. The highest tensile strength testing result is 495.17 N/mm², obtained from the welding variation with a current setting of 180 Amperes, while the lowest tensile strength testing result is from the specimen with a current setting of 160 Amperes. Similar to the strength test results from the previous examination, the variation in electric current significantly influences tensile strength. This is demonstrated by a current setting of 160 Amperes resulting in a tensile strength of 465.33 N/mm², and for a current setting of 200 Amperes, a tensile strength of 476.5 N/mm² is obtained. These results indicate that moderate electric current yields maximum tensile strength in the welding process[7–10].
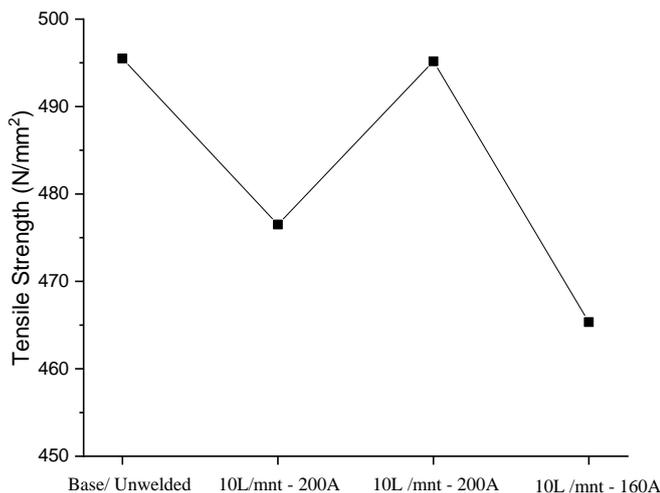

Figure 5: The Influence of Electric Current on Tensile Strength

The results of welded specimens with different CO_2 flow rates, as shown in Figure 6, yielded the highest tensile strength with a CO_2 flow rate of 10 liters/minute, while the lowest tensile strength result was obtained from a CO_2 flow rate of 5 liters/minute, with each achieving tensile strengths of 499.83 N/mm² and 497.17 N/mm², respectively. With an electric current of 180 amperes and varying CO_2 consumption, the Tensile testing results showed that the tensile strength values

remained above the tensile strength without welding. Thus, the selection of 180 amperes is highly appropriate for welding under these conditions. Similarly, the choice of CO_2 consumption is crucial; if the CO_2 consumption is too low, the tensile strength will decrease due to inadequate fusion between the welded metals[11].
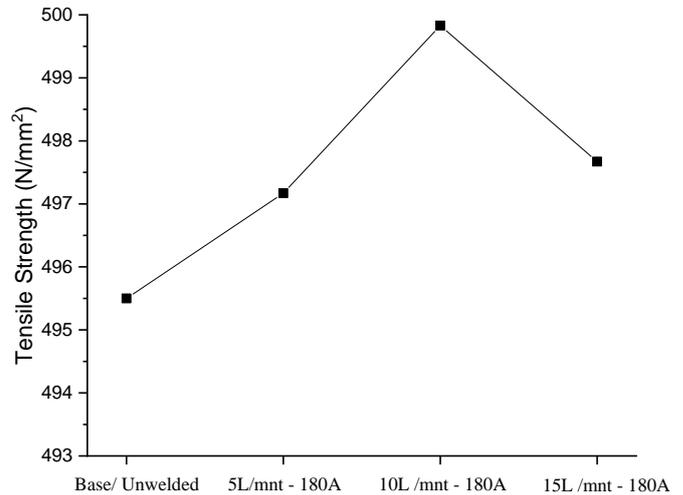

Figure 6: The Influence of CO_2 Consumption on Tensile Strength

Microstructure testing was conducted on samples with the highest and lowest tensile strength values. This was intended to evaluate the causes of failure during the welding process. From the microstructure images at a magnification of 200x produced from the SGC440 weld joint with a gas flow rate of 10 L/min and an electric current of 180 Amperes, it can be observed that there is a change in the microstructure in the welding area. The surface density of the metal produced in the base metal area is more spaced compared to the welding area.
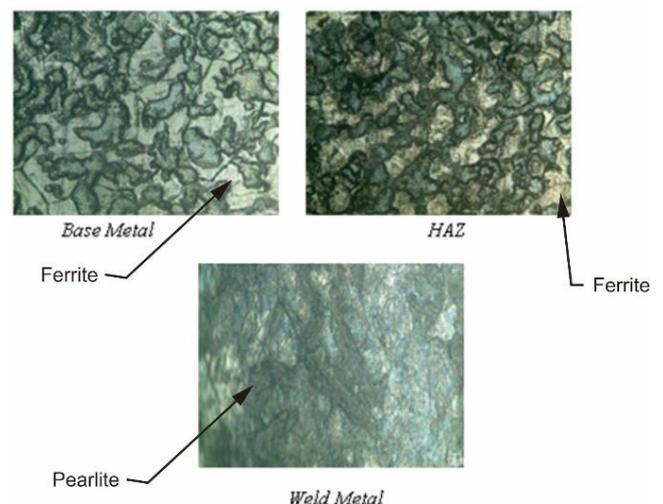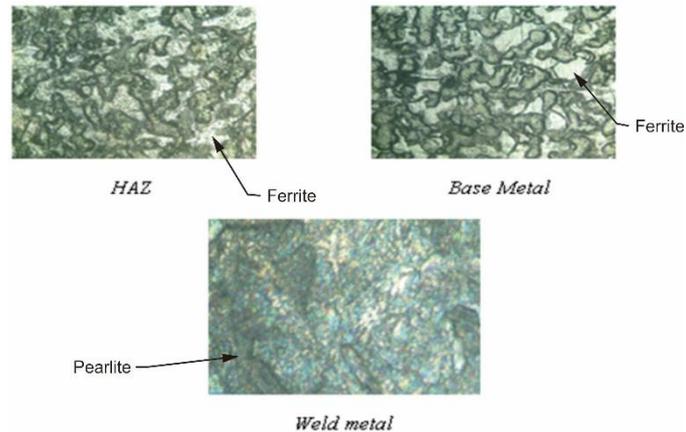

Figure 7: Microstructure Results with the Highest Tensile Test Value

In the Heat Affected Zone (HAZ) area, the boundary between the base metal area and the welding area is clearly

visible, showing different surface shapes (Figure 7). This is caused by the CO_2 gas flow not being too high or too low, and similarly, the electric current generated during Gas Metal Arc Welding (GMAW) causes the surface density produced in the welding area to form denser voids compared to the base metal area.

Figure 8: Microstructure Results with the Lowest Tensile Test Value

Figure 8 shows the microstructure at a magnification of 200x produced from the SGC440 weld joint using Gas Metal Arc Welding (GMAW) with a gas flow rate of 10 L/min and an electric current of 160 Amperes. It can be observed that there is a change in the microstructure in the welding area, where the material density produced in the base metal area is denser compared to the welding area. In the Heat Affected Zone (HAZ), the boundary between the base metal area and the welding area is clearly visible, showing different surface shapes. This is caused by the electric current being too low, resulting in a brittle welding, causing the surface density produced in the welding area to form looser voids compared to the base metal area, leading to low tensile strength during the tensile testing.

IV. CONCLUSION

The welding process with various parameter variations had been successfully carried out. Tensile test results show optimal performance in specimens with a CO_2 flow rate of 10 liters per minute and an electric current of 180 Amperes, resulting in a tensile strength of 499.83 N/mm². This finding indicates that the combination of moderate CO_2 flow rate and electric current can enhance welding strength. On the other hand, the lowest value of 465.33 N/mm² occurred in specimens with a CO_2 flow rate of 10 liters per minute and an electric current of 160 Amperes, indicating that excessively low electric current can result in weaker welding. Microstructure analysis at the setting of 10 liters per minute and 180 Amperes electric current shows the highest material structure density, yielding the most optimal tensile test results.

The HAZ (Heat Affected Zone) of the welding with this variation also exhibits a denser structure compared to other variations in the test specimens. The results of this research can serve as a guide to achieve better welding outcomes.

ACKNOWLEDGEMENT

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