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Analysis of Welding Current Variation of SMAW and GTAW Combination Welding with Double V Groove on The Mechanical Properties and Microstructure of SS304 Stainless Steel

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Abstract

In this paper, the combination of shielded metal arc welding (SMAW) and gas tungsten arc welding (GTAW) welding methods are used in a double V groove SS304 10 mm thick plate. Welding current variation of 110A SMAW/120A GTAW, 100A SMAW/130A GTAW, and 90A SMAW/140A GTAW was used to observe the effect of the welding current variation on the tensile strength and microstructure. Tensile test and metallography test were performed to observe the phenomenon. ImageJ software was used for microstructure analysis. The welding current variation resulted in higher tensile strength with the highest current on GTAW method, while a more dispersed and lathy ferrite structure was observed on the microstructure.

Keywords: SMAW, GTAW, current variation.

Abstrak

Pada tulisan ini, digunakan metode pengelasan kombinasi shielded metal arc welding (SMAW) dan gas tungsten arc welding (GTAW) pada plat double V groove SS304 setebal 10 mm. Variasi arus las 110A SMAW/120A GTAW, 100A SMAW/130A GTAW, dan 90A SMAW/140A GTAW digunakan untuk mengamati pengaruh variasi arus las terhadap kekuatan tarik dan struktur mikro. Uji tarik dan uji metalografi dilakukan untuk mengamati fenomena tersebut. Perangkat lunak ImageJ digunakan untuk analisis struktur mikro. Variasi arus pengelasan menghasilkan kekuatan tarik yang lebih tinggi dengan arus tertinggi pada metode GTAW, sementara struktur ferit lebih tersebar dan lathy diamati pada struktur mikro.

Kata Kunci: SMAW, GTAW, variasi arus.

1. Introduction

Welding is widely used in various industries as a mean to connect two metals, owing to its relatively fast and cheap process (Yogi M., 2016). One example of welding application is for storage tanks. Storage tanks are usually made from SS304 stainless steel and is used for liquid natural gas store (Abioye T.E.,

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2017). To weld thick plates, a method suitable for this application is double V groove method (Mishra D., 2020). Gas Tungsten Arc Welding (GTAW) and Shielded Metal Arc Welding (SMAW) are two of the most popular method to weld thick plates (Banik S.D., 2020).

GTAW method generally produces more even surface, lower hydrogen content, no formation of slag, and higher weld quality. This method also has the advantage of higher speed process. However, this method requires higher control of the welder and generally require higher cost (Agus, 2013; Wiryosumarto, 2000). As for the SMAW method, it generally produces more brittle as welded structure caused by oxygen which could penetrate the weld pool (Widyatmoko, 2017). However, SMAW method is simpler in the process and could be easily used in various welding position (Sustiyanti, 2018).

Based on individual strength and weaknesses of both GTAW dan SMAW method, in this paper, the combination of SMAW and GTAW method in a double V groove for joining 10 mm thick SS304 plate is observed. Variation in welding current and its effect on tensile strength is also observed.

2. Methods

Sample preparation includes the making of double V groove with 60^o angle and 5 mm groove depth. The dimension of the SS304 plate is 200mm x 200 mm x 10 mm (Figure 1), with its chemical composition available at Table 1. The electrode used are ER308 and E308-16 for GTAW and SMAW method, respectively. There are three types of samples being produced with its detail available in Table 2 and the illustration of this method is available in Figure 2.

Table 1: Chemical composition of SS304 stainless steel plate

Chemical composition (wt%)							
Fe	**C**	**P**	**Mn**	**Cr**	**Si**	**S**	**Ni**
Remaining	0.074	0.03	1.05	18.02	0.63	0.02	8.01

Table 2: Specimens of this project

No	**Specimen Name**	**Thickness (mm)**	**Welding Method 1**	**Current (A)**	**Electrode 1**	**Welding Method 2**	**Current (A)**	**Electrode 2**
1	Plate A	10	SMAW	110	E 308-16	GTAW	120	ER308
2	Plate B	10	SMAW	100	E 308-16	GTAW	130	ER308
3	Plate C	10	SMAW	90	E 308-16	GTAW	140	ER308

After the welding process, the samples are made into tensile test samples based on ASTM E8-9 standard (Figure 3) and observed for its mechanical strength using tensile test. The samples are also prepared based on ASTM E 407 and etched with aqua regia solution for metallography test (Figure 4) to observe their microstructure.

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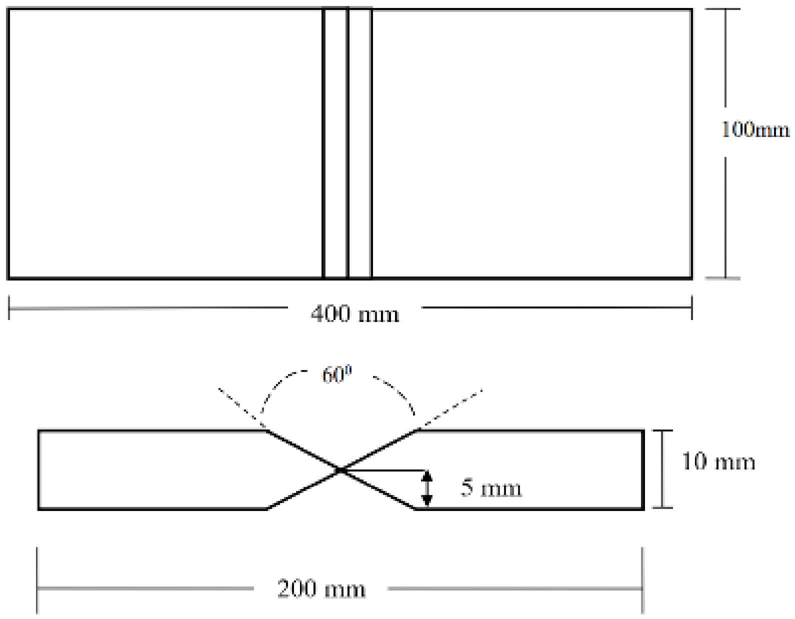

Figure 1: Specimen Dimension

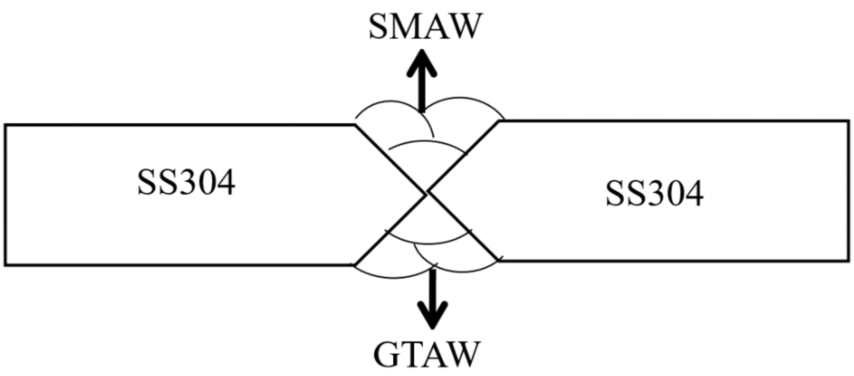

Figure 2: Illustration of welding process

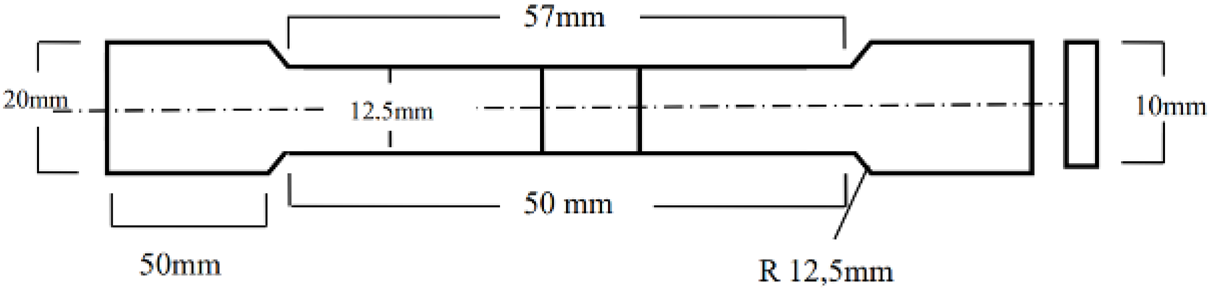

Figure 3: Tensile test sample dimension

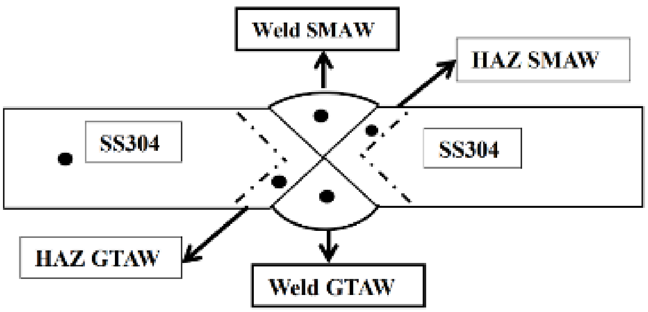

Figure 4: Metallography observation locations

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3. Result and discussion

The result of tensile test for all three samples are available in Table 3. As can be observed from the table, with the increase of welding current on GTAW method, the tensile strength increased significantly. Based on previous research by Sunandar in 2012, when comparing the mechanical properties of welded specimen using GTAW and SMAW method, the GTAW method resulted in higher strength and less defect due to its higher welding temperature even at the same welding current (Sunandar, 2012). It is highly plausible that since the weld metal with SMAW method was deposited first, when the other side of the double V groove is filled using GTAW method, the heat input from GTAW method caused an advantageous heat treatment towards the previously deposited weld.

Figure 5, Figure 6, and Figure 7 show the microstructures the three samples at the base metal, the weld metal, and high affected zone caused by both methods, respectively. Based on previous research, in austenitic stainless steel, the austenite phase will appear in lighter color compared to the ferrite phase (Harsono, 2019). It is quite pronounced that the ferrite shape in both samples B and C are different from sample A. Sample A has more elongated ferrite while samples B and C has smaller and more dispersed ferrite phase. This shape of ferrite found in samples B and C has been observed in previous research by P. V. S. S. Sridhar published in 2020. On their experiment, they found that double V groove welding of SS304 austenitic stainless steel with welding current of 365 A with varied welding speed resulted in skeletal and lathy delta ferrite (Sridhar P. V. S. S., 2020).

Table 3: Tensile test results

Sample	Welding current	Tensile strength (MPa)	Deviation	Fracture position
A	110A SMAW & 120A GTAW	609,130	22,44	Weld metal area
B	100A SMAW & 130A GTAW	635.575	8,69	Weld metal area
C	90A SMAW & 140A GTAW	647.748	11,37	Weld metal area

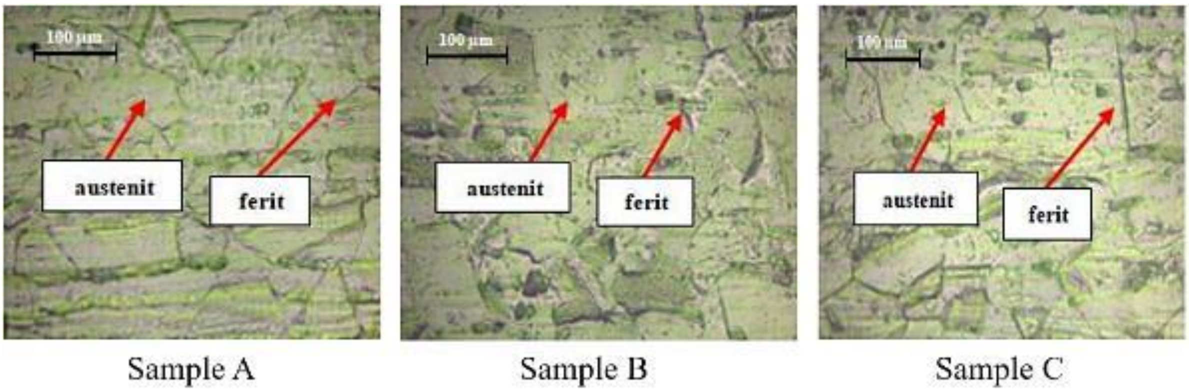

Figure 5: Microstructure on the base metal area

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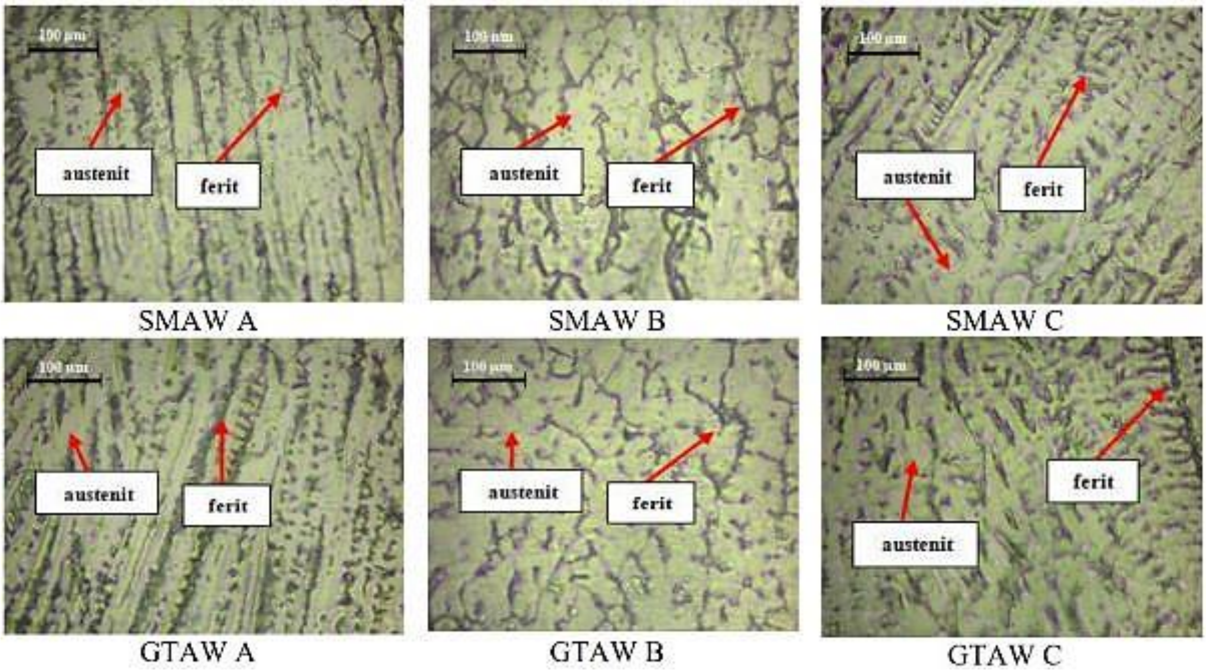

Figure 6: Microstructure on the weld metal area

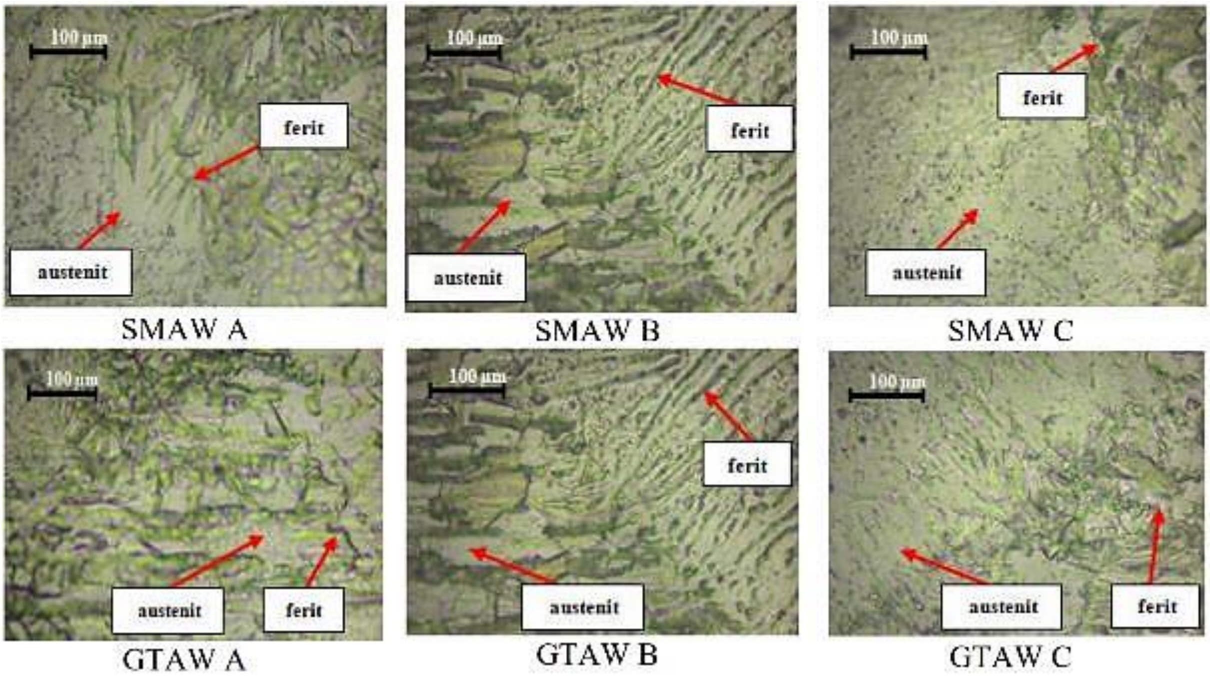

Figure 7: Microstructure on the heat affected zone (HAZ) area

Table 4: Percentage of ferrite and austenite phases in base metal area

Position	**Sample**	**Welding current**	**Percentage (%)**	
			Ferrite	**Austenite**
Base metal	A	110/120	12.78	87.22
	B	100/130	12.28	87.72
	C	90/140	12.77	87.23

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Table 5: Percentage of ferrite and austenite phases in weld metal and heat affected zone area

Position	Sample	SMAW Welding current 1 (A)	SMAW Percentage (%) Ferrite	SMAW Percentage (%) Austenite	GTAW Welding current 2 (A)	GTAW Percentage (%) Ferrite	GTAW Percentage (%) Austenite
Weld metal	A	110	21.47	78.53	120	20.78	79.22
	B	100	20.84	79.16	130	19.76	80.26
	C	90	20.68	79.35	140	17.4	82.60
Heat affected zone	A	110	12.46	87.54	120	12.89	87.11
	B	100	12.73	87.27	130	13.06	86.94
	C	90	13.29	86.71	140	13.38	86.62

Table 4 and Table 5 show the percentage of ferrite and austenite phase in base metal and in weld metal and heat affected zone, respectively. This percentage is obtained using ImageJ software, using the image black and white threshold to single out the darker area from the lighter area (Schneider C.A., 2012). The percentages of both phases in heat affected zone is not significantly changed, only an increase in approximately one percent of ferrite phase with welding current combination of 100/130 A and 90/140 A. A more distinct change is observed in the weld metal of each sample. Sample A has the highest percentage of ferrite phase with 20.78% at the weld metal deposited using the GTAW method. At the same location, sample B and C is observed to have less ferrite percentage with 19.76% and 17.4%, respectively. At the weld metal deposited using SMAW method, the same trend is still observed, although the difference is not quite pronounced.

It was explained that when the colling rates are high, delta ferrite is formed because of the limited diffusion while ferrite is transformed into austenite (Lippold J.C., 2015). In this case, the diffusion distance is rather low, which would cause in the decrease of concentration gradient, therefore enhancing the phase transformation to be more efficient, resulting in less spacing between the ferrite laths (Mirshekari G.R., 2014). It is found that a certain quantity of delta ferrite is rather desirable because it would prevent weld metal from hot cracking (Kou S., 2003; Lippold J.C., 2015).

4. Conclusion

Appropriate welding current combination of SMAW and GTAW method has shown to increase the tensile strength up to 647.748 MPa. It has also been observed that the higher welding current using GTAW method caused a desirable ferrite phase shape transformation from large dendritic ferrite to skeletal and lathy ferrite phase shape.

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