RESEARCH ARTICLE | OCTOBER 27 2023

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AIP Conf. Proc. 2837, 040015 (2023)
https://doi.org/10.1063/5.0151314

Thin Plate Welding of Al 5083 Alloy by GMAW Applied for Electric Substations Equipment

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Abstract. In order to fill the manufacture demand of electric substation equipment, materials with the characteristics of rust-resistant, lightweight and easy to find are required. Aluminum 5083 alloy is the best candidate to use because one of advantages is excellent thermal conductivity. Gas Metal Arc Welding (GMAW) is used because it has high welding efficiency, it does not need to change welding wire frequently, can be used for all types of materials and welding positions, and does not produce scale or slag. The purpose of this research is to evaluate the GMAW welding parameters on the mechanical properties of Al 5083 alloy. The specimen of Al 5083 alloy is cut into V Groove with 30° or 60° angle each side, for 6 pieces with dimension of 300 mm length and 150 mm width, before welding process. The welding process is done using the manipulator machine with constant speed and various currents followed by mechanical testing. The mechanical testing results obtained, there is no significant difference on the tensile strength results of all specimens with different welding parameters. However, the elongation percentage result obtained, the highest strain is about 17% of the Al 5083 alloy thin plate specimen with 225 A current. It can be concluded that the Al 5083 alloy material through the GMAW process with appropriate has met the requirement of mechanical properties to be applied for the electric substation equipment.

INTRODUCTION

The welding process is usually used in engineering applications, for example in the manufacturing of automotive components i.e. chasis, engine and exhaust system; infrastructure i.e. aircraft components, power generating, electrical substations, industrial and piping equipment, telecommunication infrastructure components; and electronics components i.e. medical and analytical equipment, battery components, magnets and motor, electromagnetic compatibility and noise reduction. Gas Metal Arc Welding is often used by the engineers due to has a high welding efficiency without replacing the welding wire often, able to use for all types of materials and welding positions, and it does not produce crust. GMAW is the welding process with the inert gas, which the electrodes used are not coated and can be supplied continuously form of coils [1–7].

Aluminum is chosen due to good conductors of electricity, good conductor of heat, lightweight and strong, resistant to corrosion [8]. Compared to steel, aluminum has softer properties but has a lighter lifetime than steel. One of them is the aluminum Al 5083 series [3,8]. The aluminum element is combined with Magnesium (Mg) type and form Al-Mg (5xxx series) alloys [3,8]. Aluminum Al 5083 alloy has properties that are resistant to corrosion, especially caused by seawater [3,8].

In conducting welding, the connection will work well if there is a metallurgical mixing between the parent metal and additional metals [1,3,7]. During the welding process, the area under the weld metal will experience expansion while the area under the metal will hold it [9]. The part that expands will cause compressive stress while the part below it is against tensile stress. During the cooling process of the metal, the area under the weld metal experiences

International Symposium on Advances in Mechanical Engineering 2021
AIP Conf. Proc. 2837, 040015-1–040015-6; https://doi.org/10.1063/5.0151314
Published by AIP Publishing. 978-0-7354-4661-8/$30.00

tensile stress and the area underneath is resisting with pressure [9]. The voltage that occurs on this welded plate continues to exist to room temperature. Stress that occurs in the metal is called residual stress [9,10].

The selection of current in the welding process will have an impact on the tensile strength of welds, currents that are too high will result in overheating, causing a breakdown of the base metal during the welding process and the use of currents that are too low will result in a less than maximum copy which will result in a reduced level of the tensile strength of the weld material [3,9]. Aluminum has a high oxide layer, so an appropriate current is needed to melt the metal surface and base metal [8].

The welding current will also have an impact on the heat input that happened, maximum tensile strength can be obtained if sufficient heat input will make the weld metal and base metal diffuse properly and not expected to cause defects in welds [9]. Welding rate is also a factor that will affect the tensile strength of welding results. The greater the welding speed, the value of the tensile strength is higher. Welding with aluminum material must be carried out with an appropriate welding speed to prevent melting at the core due to excessive heat because of the slow welding speed [10, 11].

In this research focused on the quality of the results of welding is influenced by the presence of heat energy which means that thermal energy is affected by the welding current, welding voltage, and welding speed. The relationship of the welding current, welding voltage and welding speed produce welding energy known as heat input are discussed in detail.

MATERIALS AND METHODS

Al 5083 plate with length, width and thickness dimension is 300 mm x 150 mm x 12 mm is cutted into 6 pieces. The welding was carried out using GMAW, followed by single V Groove type with 30º or 60º angle at each sides or back grinding, as shown on Figure 1. The type of welding electrode is ER 5356 with 1.6 mm diameter. The chemical composition of Al 5083 alloy is shown on the Table 1.

TABLE 1. Chemical compositions of Al 5083 alloy.

Grade	Si	Fe	Cu	Mn	Mg	Cr	Ni	Zn	Al
5083	0.400	0.400	0.100	0.40-1.0	4.0-4.9	0.05-0.25	-	0.250	remains

The preheating process was carried out before the welding process, in order to remove the liquid on the surface, and to avoid the welding defects. Furthermore, the other purposes of preheating are reducing the welding area humidity and lowering the gradient temperature. The preheating process which applied for Al 5083 alloy is shown on Figure 2. The tensile specimen is preparing by milling machine with the dimension by following the standard of ASTM E8/E8M-13a [12–14]. Tensile test is done by using tensile strength machine HT – 9501 type and H-200 kN / 20 T model. The test was conducted by using 3 specimens of Al 5083 alloy with 12 mm thickness, 3 variable currents and 20 ton load. The hardness test was carried out using macro hardness HVM-1000 type with 4.9 N load. In addition, the macro hardness test was conducted for 3 times at each ampere with the constant load to validate the result. The heat input is calculated using the following Equation 1, where Q is the heat input (kJ/mm), η is the thermal eficiency (%), V is the voltage (V), I is the current (A) and v is the welding speed (mm/min) [15,16].

$$Q = \eta \frac{V.I.60}{v} \tag{1}$$

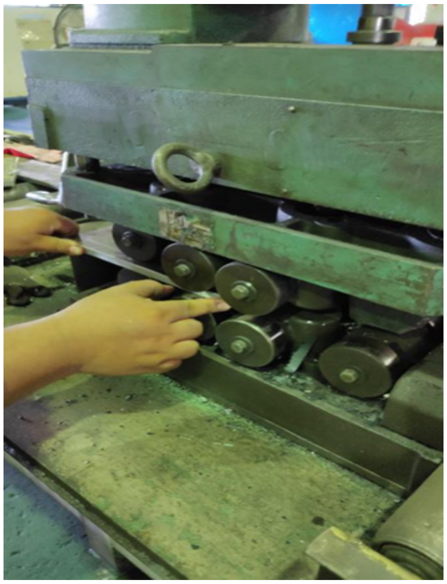

FIGURE 1. V groove processing.

FIGURE 2. Preheating process.

RESULTS AND DISCUSSIONS

The specimen of Al 5083 alloy is cutted by following V Groove with 30º or 60º each side, for 6 pieces with dimension of 300 mm length and 150 mm width, before preheating and welding process. The welding process is carried out using the manipulator machine with constant speed and various currents followed by mechanical testing. Figure 3 shows the plate shape of Al 5083 alloy specimen before welding. In addition, the appearance of the specimen after welding process is shown on Figure 4.

FIGURE 3. Specimen of Al 5083 alloy before welding.

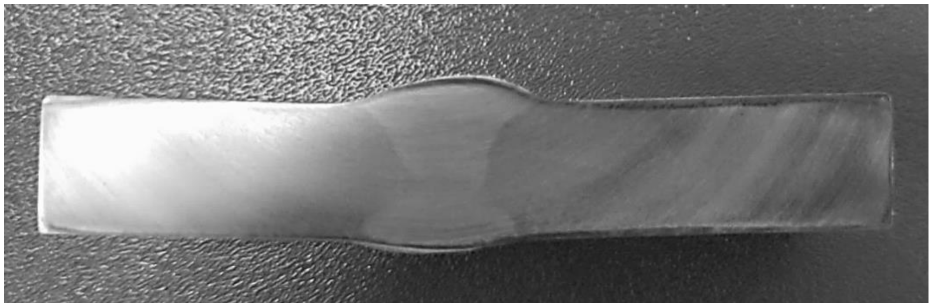

FIGURE 4. Specimen of Al 5083 alloy after welding.

The testing method is carried out by following the ASME Section IX standard using the tensile test machine HT – 9501 model H-200 kN or equivalent to 20 T load [17]. Table 2 shows the Al 5083 alloy with the current of 225 A has the lowest heat input of 2.376 kJ/mm. Meanwhile, the Al 5083 alloy with the current of 250 and 275 A has the higher heat input of 3.24 and 3.564 kJ/mm, respectively. The heat input increase is obtained by increasing the current and voltage during the welding process.

TABLE 2. Result of heat input calculation

Current [A]	**Voltage [V]**	**Heat Input [kJ/mm]**
225	22	2.376
250	25	3.24
275	27	3.564

The tensile test result, Al alloy with the current of 225 A has the yield strength of 273.50 N/mm^2 and the tensile strength of 300.50 N/mm^2. Al alloy with the current of 250 A has the yield strength of 278.82 N/mm^2 and the tensile strength of 294.25 N/mm^2. Al alloy with the current of 275 A has the yield strength of 277.96 N/mm^2 and the tensile strength of 293.85 N/mm^2. According to ASME standard the average of the tensile strength of Al 5083 alloy is 275 N/mm^2 [17]. Based on the results of the average tensile strength of Al 5083 alloy with 3 difference variable of applied current for welding process is slightly higher if compared to the ASME Section IX standard. From this results are proove that the tensile strength is increase by increasing the applied current, voltage, as well as increasing the heat input on the welding process. Figure 5 is shows the graph of strength – elongation of Al 5083 alloy with difference variable of applied current of 225 A, 250 A, and 275 A.

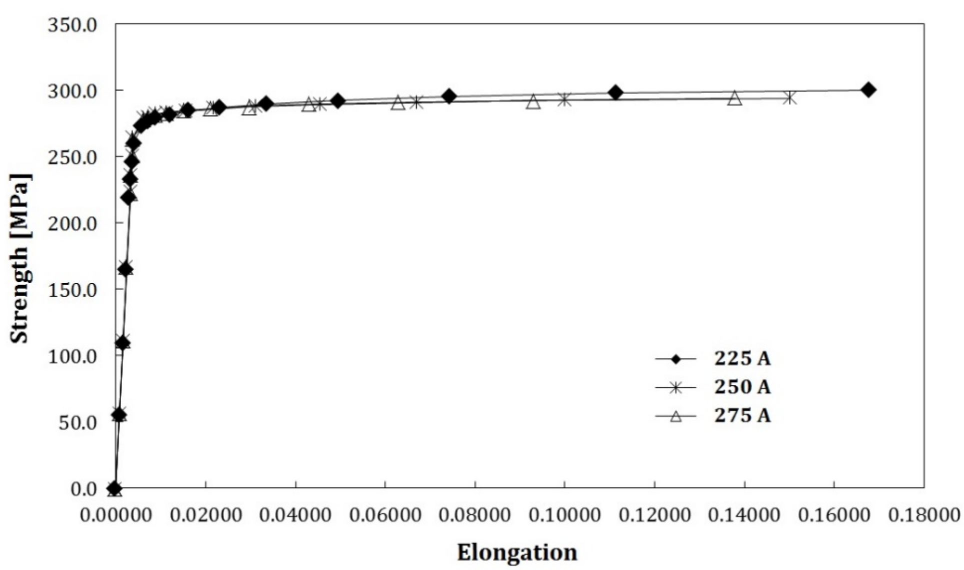

FIGURE 5. Strength – elongation graph of Al 5083 alloy with difference applied current.

The Vickers Microhardness testing results is presented in the Figure 6. The testing location for Vickers microhardness is carried out in the welding area or kown as heat affected zone (HAZ). The average of Vickers Microhardness of 225 A applied current is 103.633 HV with the maximum and minimum point is 104.9 A and 101.8 A, respectively. The average of Vickers Microhardness of 250 A applied current is 113.7 HV with the maximum and minimum point is 116.6 A and 110.4 A, respectively. The average of Vickers Microhardness of 275 A applied current is 121.4 HV with the maximum and minimum point is 127.5 A and 116.8 A, respectively. The highest number of Vickers microhardness is obtained on the Al alloy specimen with 275 A applied welding current.

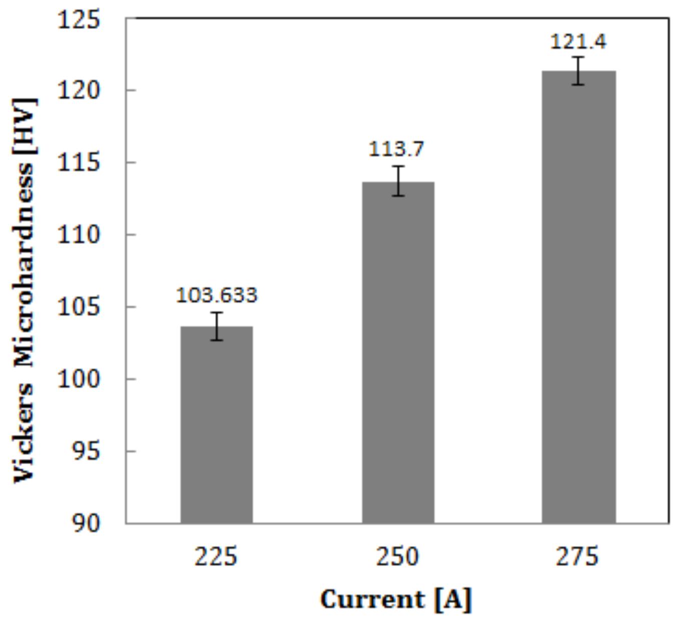

FIGURE 6. Vickers microhardness testing results.

CONCLUSIONS

The mechanical properties of thin plate welding of Al 5083 alloy has investigated by difference applied current and voltage, as well as heat input variable of GMAW process. The tensile testing results obtained, there is a slightly difference on the strength results of all specimens with difference welding parameters. However, the elongation percentage result obtained, the highest strain is about 17% of the thin plate Al 5083 alloy specimen with 225 A applied current. Thus, from the mechanical testing result shows that Al 5083 alloy have better properties by increasing heat input through GMAW process. Therefore, it can be concluded that the Al 5083 alloy material can be improved the mechanical properties through the GMAW process variable and enable to be applied for the electric substation equipment as well as other applications.

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