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EFFECT OF TEMPERATURE VARIATION OF STATIC THERMAL TENSIONING ON ANGULAR DISTORTION AND MICROSTRUCTURE BEHAVIOR OF GMAW WELDED SUS 304 STAINLESS STEEL PLATE

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Abstract. Due to its rust resistance properties, the use of stainless steels, especially SUS304 for industrial equipment is increasing. The manufacturing process that is often used is GMAW welding. One of the disadvantages of SUS304 is the occurrence of distortion and sensitization when welded. In this study, the effect of temperature variations of Static Thermal Tensioning on angle distortion and microstructure behavior due to GMAW welding of SUS 304 T-joint plates was studied. Heating by electric heater is given to both parts of the base metal plate SUS 304 5mm thick with temperature variations of 200 ºC, 250 ºC and 300 ºC. Cooling water with a temperature of 24 ºC is provided on the back side of the welded track. Welding using filler ER 304 with a diameter of 0.8 mm with welding parameters such as welding current, voltage, gas flow and travel speed controlled at 75 A, 22 V, 10 l/min and 8 mm/s, respectively. Angular distortion of welding results for each treatment temperature variation was measured using a bevel protractor, and perform metallographic test to knowing the microstructural behavior. The results of the measurement of the average angular distortion of three repetitions show that at a temperature of 250 C static thermal tensioning produces the smallest angular distortion of 3º70', compared to other temperature variations which produce angular distortion 4º45' at 200 ºC and 3º86' at temperature 300 ºC. The findings of the largest Cr (carbide) deposits due to sensitization were found at a temperature of 300 ºC at 16,49% and the lowest at a temperature of 200 ºC at 7,05%

Keywords: static thermal tensioning,sensitization, SUS 304,GMAW, angular distortion.

1. INTRODUCTION

Stainless steels are an important class of engineering materials that have been used widely in a variety of industries and environments due to their high corrosion and oxidation resistance property [1]. Due to its rust resistance properties, the use of stainless steels, especially SUS304 for industrial equipment is increasing. Austenitic stainless steels are used in the pressure vessels, chemical, transportation, medical industry due to their superior mechanical properties [2]. The manufacturing process that is often used is GMAW welding. However, this technology in its traditional form has disadvantages because the high temperature involved generates thermal expansion, shrinkage, and microstructural transformations [3]. The most concerned of the disadvantages of SUS304 is the occurrence of distortion and sensitization when welded.

Non-uniform heating and cooling during welding results in non-uniform expansion and contraction of the weld base and its surroundings, which results in residual stresses and unwanted deformations in the welded joint [4]. In the process of welding SUS 304 material, the thermal expansion and contraction produced is very large so that it can cause defects or failures in welding. Additional works such as post weld heat treatment and welding repairs need to be done to correct distortions and reduce the residual stresses [5]

[6] has done optimization of welding parameter relationship with distortion angle and weld depth. The results show the smallest angle distortion value of 0.139 [radian] and penetration depth of 2.77 [mm] can be achieved with a variable welding using a plate length of 355.75 [mm], with a current of 250 [A] and a welding speed of 30 [cm/min].

Thermal tensioning is a welding method by adding active cooling that moves behind the welding torch and a heater that is placed next to the welding line. The residual stress that occurs in the weld area also decreases and bends distortion that often occurs in conventional plate welding can become almost flat when using this method [7].

One of the Thermal Tensioning methods is Static thermal tensioning (STT), where the working principle of this method is in the form of thermal tensioning to against thermal stress due to welding. Static thermal tensioning (STT) method can minimize the distortion that occurs in the AA5083 aluminum plate with a thickness of 3mm where the optimal distortion reduction occurs at a heating temperature of 200 ºC [8].

Angular distortion can occur in the welding of T joints. This distortion is even greater if the welding material used is stainless steel, because in austenitic stainless steels thermal expansion is high and heat conduction is low [9,10]. Effect of heat input can influence both detrimental and beneficial effect on the material microstructure which is then directly influencing corrosion resistance of materials [11]. The heat input of welding will cause sensitization (formation of Cr precipitation at grain boundaries) in the HAZ; acceleration of localized attack in the presence of chloride ions [12, 13]. Sensitization it self leads to degradation of corrosion resistance as well as the mechanical properties [14]. then Further research is needed to overcome the problem of angular distortion and sensitization phenomenon in stainless plate welding, especially SUS 304, considering its very wide use in industry.

2. METHODS

2.1 Specimen and Equipment Preparation

The welding specimen is a SUS 304 plate with dimensions of 170 mm in length, 130 mm in width and 5 mm in thickness. Before tackweld to form a T joint, the plate is drilled with a diameter of 2 mm in several positions as a place for installing several thermocouples as shown in Figure 1. below:

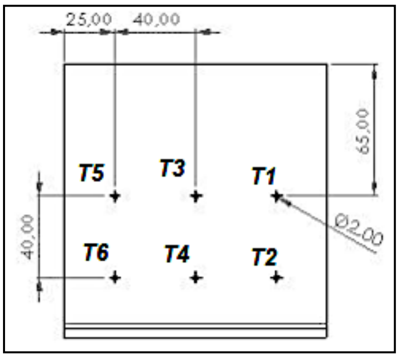


Figure 1. Thermocouple hole position

Tack weld the specimen at an angle of 90º which is then measured using a bevel protractor to ensure that it is correct. Then to record the temperature distribution during the welding process, several thermocouples are installed As shown in Figure 2. below:

Figure 2. Tackwelded Specimens and Installed Thermocouples

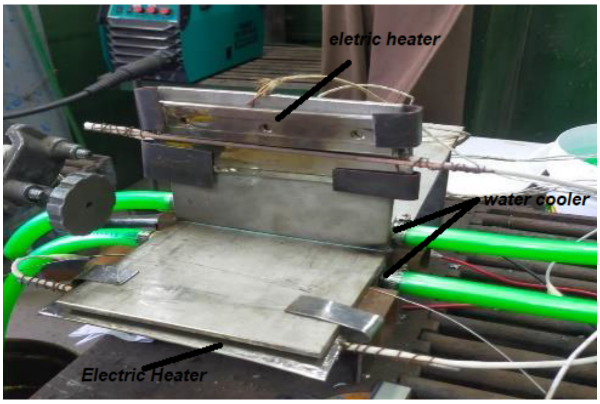


Figure 3. Instaled Electric Heater and Water Cooler

The flat electric heater is mounted on the back side of the base metal plate. While the water cooler is installed on the back side of the welding line as shown in figure 3. To keep the travel speed constant, the welding gun is mounted on a gas cutting machine that can move in a straight line with adjustable speed, as seen in Figure 4.

Figure 4. Gas Cutting Machine for Constant Travel Speed

2.2 Method of Collecting Data

GMAW welding is performed on specimens with three repetitions for each temperature variation of static thermal tensioning, namely at temperatures of 200 ^{o}C, 250 ^{o}C and 300 ^{o}C. Welding parameters as travel speed, current, gas flow and voltage are controled, respectively at 8 mm/s, 75 A, 10 l/min and 22 volt. Welding temperature distribution on each installed thermocouple recorded every second on the data logger. Angular distortion measured by bevel protractor, and perform metallographic tests to see the microstructural behavior that occurs. the results were compared between treatments.

3. RESULTS AND DISCUSSION

3.1 Angular Distortion

The results of the measurement of angular distortion on the SUS 304 plate from GMAW welding with T joints are presented in Table 1.

Table 1. Angular Distortion of Static Thermal Tensioning Treatment with Temperature Variation

Repeatation	Distorsion (°)		
	Temperature 200 °C	Temperature 250 °C	Temperature 300 °C
1	4.73	2.8	3.97
2	4.93	2.6	3.9
3	3.7	2.95	3.7
Mean	4.45	2.78	3.86

The comparison graph of the average angular distortion is shown in Figure 5. From the graph it can be seen that there are differences in angular distortion due to temperature variations in the static thermal tensioning treatment given to the plate when welding. The average angular distortion that occurs at the static thermal tensioning temperature of 200 °C is 4.45° while at the temperature of 250 °C and 300 °C, it is 2.78° and 3.86°, respectively. It appears that the thermal static tensioning temperature of 250 °C produces the lowest angular distortion compared to 200 °C and 300 °C.

3.2. Temperature Distribution

The temperature distribution during welding with static thermal tensioning treatment with temperatures of 200 C, 250 C and 300 C can be described in graphical form as shown in Figure 6.

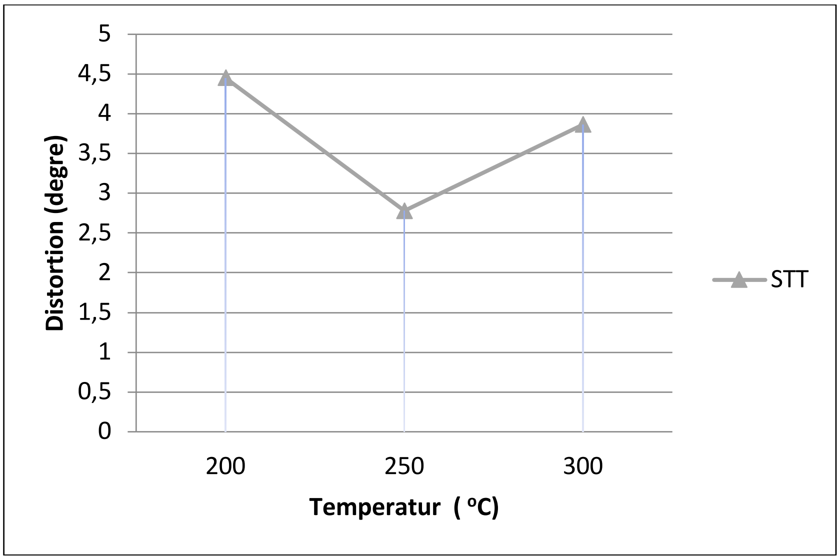
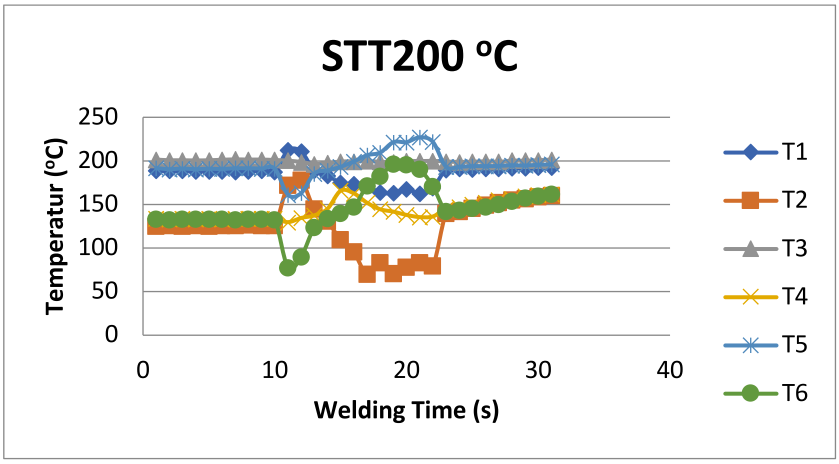
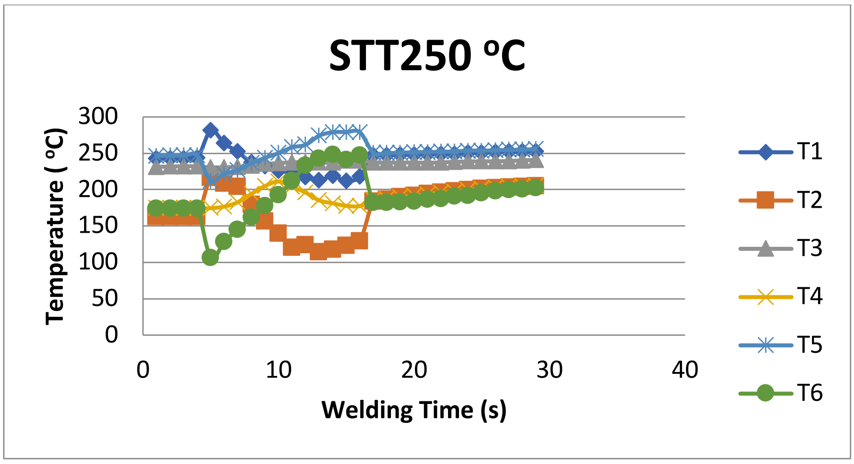


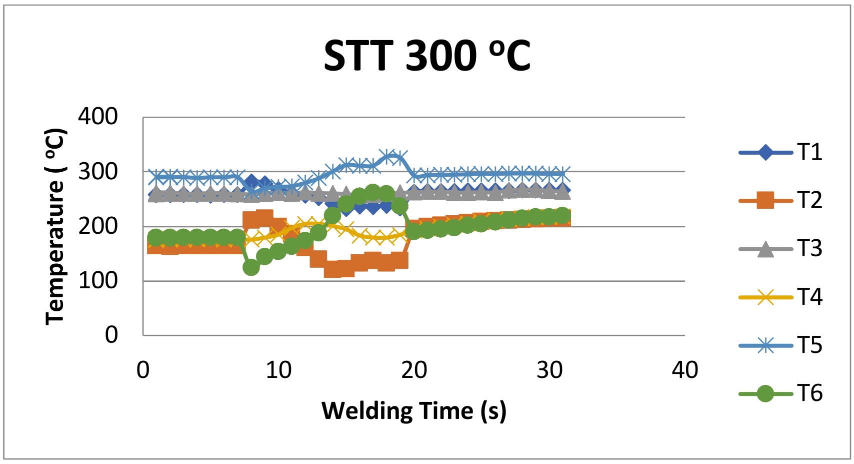
Figure 5. Comparison graph of angular distortion that occurs at several treatment temperatures



a



b



c

Figure 6. (a,b,c) Temperature distribution During welding

According to figure 6 (b), the Static Thermal Tensioning treatment has a relatively low angle distortion of 2º78' at a temperature of 250 C, in this treatment the temperature on the base metal is more evenly distributed and on the welding line the cooling occurs more efficiently, so that the temperature on the welding line decreases and the resulting distortion is lower.

3.3 Microstructure

Optical micrographs of weld metal are as shown in Figure 7 below

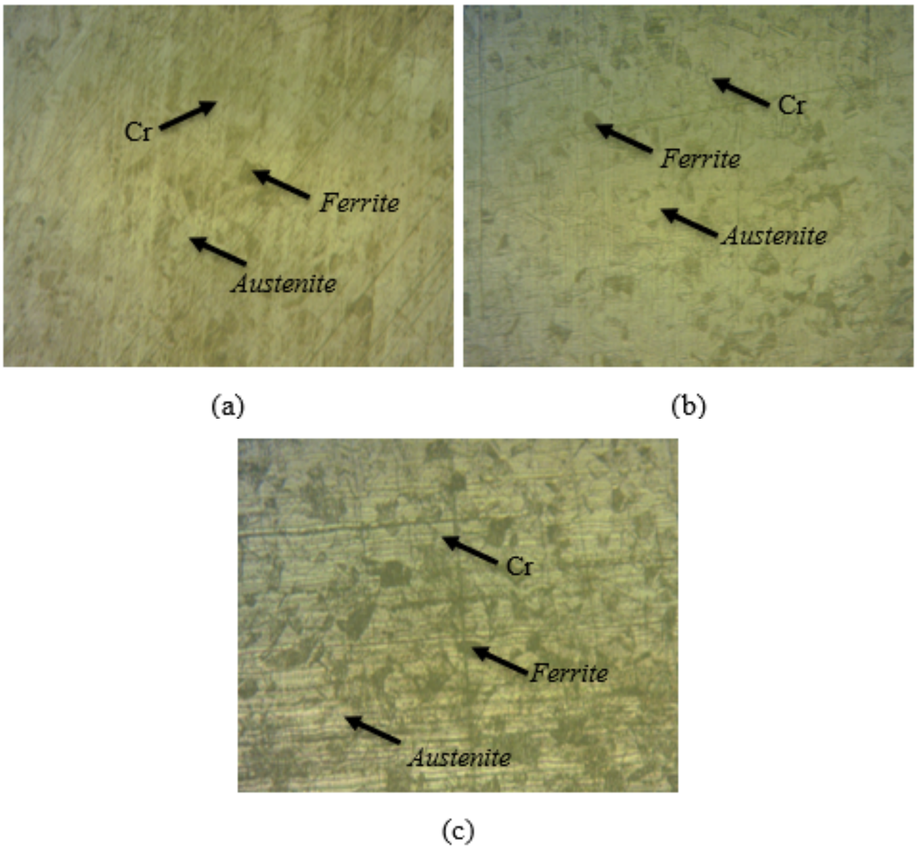


Figure 7. Optical micrographs of weld metal (a) 200 °C, (b) 250 °C, and (c) 300 °C

Fig 7 (a),(b) and (c) show the microstructure of the HAZ on the Static Thermal Tensioning 200°C, 250°C, 300°C treatment method. From the micro photos taken, the structure consists of 3 phases, Ferrite, Austenite and Cr. Ferrite structure is dark in color and austenite is light in color and Cr deposits are in the form of ditch around the grain boundaries.

Table 2. Recapitulation of sensitization percentage of Static Thermal Tensioning treatment

Sensitization *STT*					
200°C		250°C		300°C	
Pixel	Percentage (%)	Pixel	Percentage (%)	Pixel	Percentage (%)
53480	7,05%	71156	9,38%	123195	16,49%

The higher the STT treatment temperature, it can be seen in the figure that the denser the grains are in the HAZ area. Also followed by Cr (Carbide) deposits in each treatment, as high as the temperature treatment given, it can be seen in the Table 2. that the more Cr deposits at the grain boundaries that arise, means when the sensitization time and temperature increased carbide precipitation at grain boundary also increased [15]. The highest percentage of Cr was 16.24% in the STT treatment at 300°C.

4. CONCLUSION

Referring to the discusion of this study can be concluded as follows:

a. The optimal static thermal tensioning temperature to obtain the smallest angular distortion in the welding of the 5 mm thick SUS304 T plate joint with the GMAW process is 250 °C. where at this temperature the angular distortion value that occurs is 2° 78'.

b. The most even temperature distribution on the SUS 304 plate welded by the GMAW process is in the Static thermal tensioning treatment with a temperature of 250 ^{o}C
c. The optimal static thermal tensioning temperature to obtain the lowest sensitization effect in the welding of the 5 mm thick SUS304 T plate joint with the GMAW process is 200 ^{o}C. where at this temperature the percentage of carbide deposition is 7,05 %.

5. REFERENCES

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