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CORROSION RATE AND RESIDUAL STRESS ON GMAW WELD JOINT OF SUS 304 STEEL WITH STATIC THERMAL TENSIONING TREATMENT

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Abstract. One of the biggest problems in the metal welding process, especially for stainless steel, is the occurrence of large distortions. To reduce distortion during the welding process, it is recommended to provide secondary thermal like Static Thermal Tensioning. However, the provision of secondary thermal is allegedly able to decrease residual stress but reduce the corrosion resistance of stainless steel . In this study, variations in temperature of static thermal tensioning were applied during the GMAW process of SUS 304 plate. Furthermore, the results of the welding were made test specimens to determine the residual stress and corrosion rate of each temperature variation. The measurement of the residual stress using slitting method and measurements of the corrosion rate was carried out with the Autolab PGSTAT 204 potentiostat. The measurement results showed that residual stress of the welding results decrease along with the increase in the temperature of the Static Thermal Tensioning treatment where the treatment temperature of 200 ºC have highest residual stress at 113.79 MPa, followed by the treatment temperature of 250 ºC with 105.67 MPa value, and the lowest residual stress at temperature of 300 ºC with 77.82 MPa value. But, the corrosion rate value at the opposite way where the treatment temperature of 200 ºC produces the lowest corrosion rate, which is 0.70 mm/year, followed by the treatment temperature of 250 ºC of 0.99 mm/year and at a treatment temperature of 300 ºC with a corrosion rate of 1.27mm/year.

Keywords : GMAW, static thermal tensioning, corrotion rate, residual stress, SUS 304.

1. INTRODUCTION

SUS 304 steel is an austenitic material known for its resistance from rust. Therefore, this type of steel is widely used in various industries such as the chemical, food, and pharmaceutical industries [1]. In manufacturing SUS 304 steel, welding is often used to join two parts together. However, the welding process on SUS 304 steel has a weakness because high temperature involved results in thermal expansion, shrinkage, and microstructural transformation [2]. This makes SUS 304 steel prone to welding defects such as corrosion rates decreased due to sensitization and residual stresses.

The non-uniform heating and cooling during welding process creates non-uniform expansion and contraction of weld joint and base metal, resulting in residual stress [3]. Residual stress occurs when a material is affected to a non-uniform temperature change, which is called thermal stress [4]. The residual stress cannot be seen with the naked eye, but actually residual stress becomes a constant load which causes value of workload increase when there is an external load [5].

Various methods have been carried out to reduce weld defects, one of the method is static thermal tensioning which is proven to reduce distortion, increase fatigue resistance, and reduce residual stress [6,7]. Static thermal tensioning is a treatment when two base metals are heated to a certain temperature away from welding area and cooled behind the weld joint. Static thermal tensioning treatment can reduce longitudinal plastic stress formed during the welding process in the weld area and base metal [8].

However, the heat input can affect on microstructure of the material which can directly affect corrosion resistance of material [9]. Corrosion is damage that occurs to a material caused by environment where material is located. Corrosion is very detrimental both in economy and human livings. It is estimated that about 5% of the industry's national income is spent on corrosion prevention and maintenance of lost or contaminated products due to corrosion reactions [10]. One of the causes of corrosion is sensitization.

Sensitization itself causes degradation of corrosion resistance and mechanical properties [11]. Sensitization causes the deposition of chromium carbide upon cooling, so that the area around the grain boundaries is poor in chromium (<12%). So, when objects are in a corrosive environment, grain boundary corrosion tends to occur [12]. Therefore, further research is needed to overcome residual stresses and observe corrosion rates in welding SUS 304 steel, because this material use widely in industry.

2. METHODS

2.1 Specimen and Equipment Preparation

The material used in this research is SUS 304 steel. Size of the specimen used is 170 x 150mm with 5 mm material thickness. As shown at Fig 1. six points hole also made for the thermocouple sensor place with 2 mm hole diameter for the placement of 37.5 mm thermocouple sensor. In order to record the temperature every second when welding takes place, thermocouple sensor place back plate.

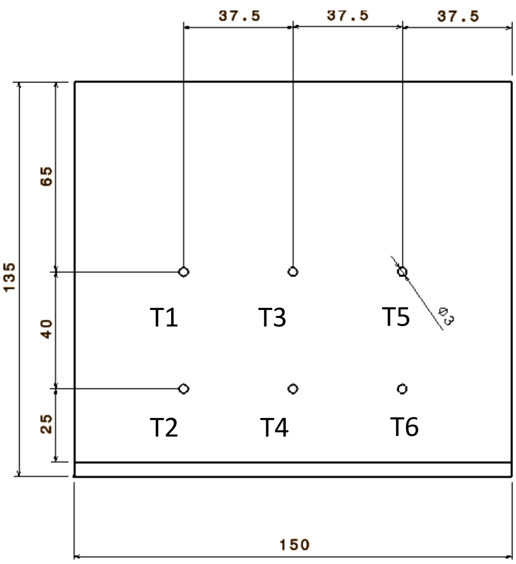


Figure 1. Thermocouple hole position

Tack welds are made on specimens at angle of 90° using a bevel protactor for more precise measurements. For the static thermal tensioning welding method, the heater installation is positioned on the T Joint specimen base metal using flat heater as in Fig 2. The welding process uses a travel motor as a welding aid so the welding speed can be determined constanly at 8.3mm/sec. The travel motor is placed parallel to the welding line

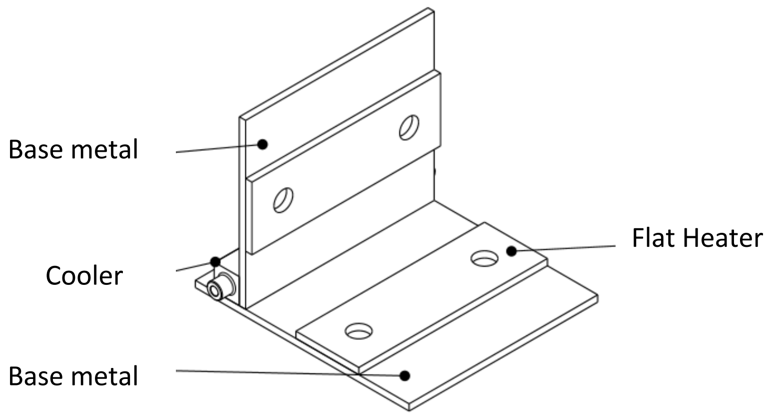
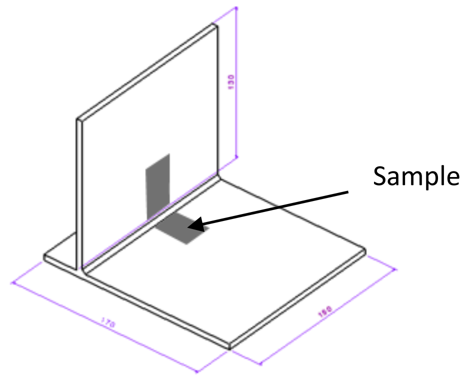
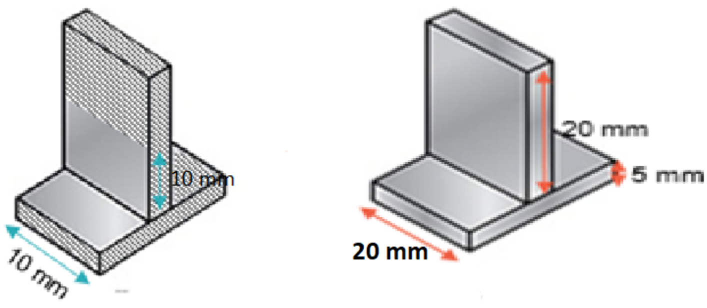


Figure 2. Electric Heater and Water Cooler Installation

The workpiece that has been prepared for testing is cut into smaller sizes both for corrosion rate testing and residual stress testing. Both are taken from the center point of the workpiece (a). The size of the specimen used for testing corrosion rate has dimensions of 10x10 cm in the area that is not shaded (b) and for slitting is 20x20 cm (c) which can be seen in Fig 3.



(A)



(B) (C)

Figure 3. Specimen Preparation

2.2 Method of Collecting Data

2.2.1. Welding Method

In this research, three variations of flat heater temperature was given including temperatures of 200°C, 250°C and 300°C. Welding parameters are determined like travel speed 8.3m/s, current 75A, voltage 22 V and gas discharge 10 l/min. An illustration of the welding process can be seen in the Fig 4.

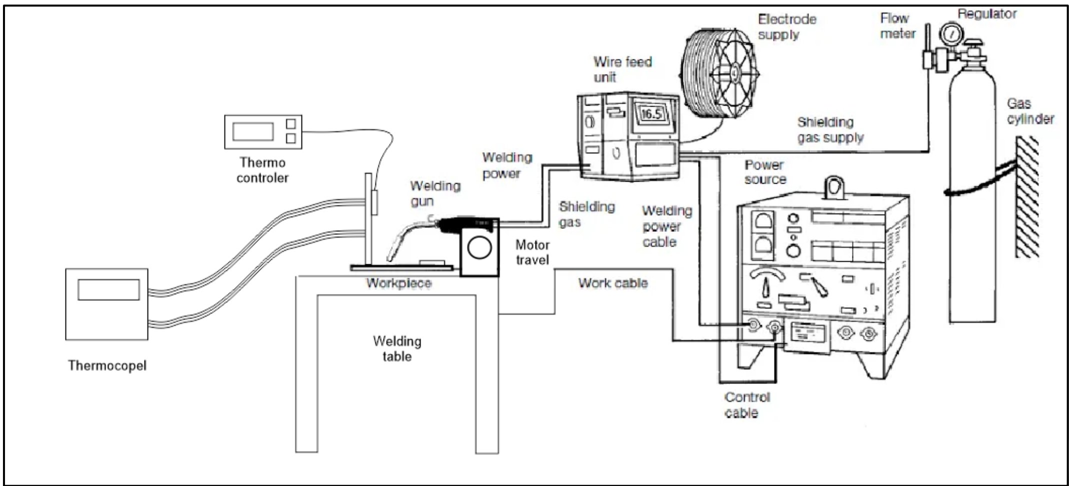


Figure 4. Welding Installation

2.2.2. Corrosion rate test

In order to determine corrosion rate on the SUS 304 test specimen, three electrodes are arranged by pairing each electrode. Then the three electrodes were immersed in test glass contained 150 ml of 3.5% NaCl liquid. From potentiostat, the cable connected to a computer that already contains NOVA 1.11.2 software version. The installation of corrosion testing equipment using a potentiostat can be seen in Fig 5. and standard for corrosion rate measurenemnts with electrochemical method using ASTM [13].

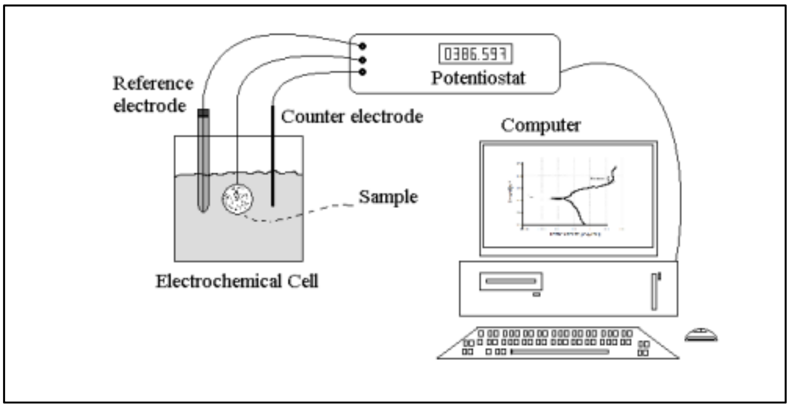


Figure 5. Potensiostat Installation

2.2.3. Slitting Test

In the slitting test, strain gage sensor is attached to the back of specimen as shown at Fig 6.Then an eighteen mm incision is made with a 45° slope using an wirecut electrical discharge machine. The results of each millimeter of strain are recorded using *wavejumper* software which is connected to a strain amplifier which reads the strain on the strain gage sensor.

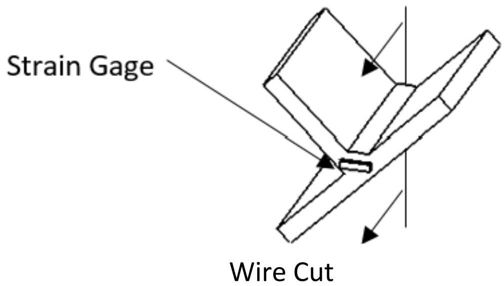


Figure 6. Slitting Method on T-Joint

3. RESULTS AND DISCUSSION

3.1 Distribution of Temperature

The temperature distribution during the welding process with static thermal tensioning temperatures at 200 ºC, 250 ºC, and 300 ºC shown in Fig 7. as a graphical form.

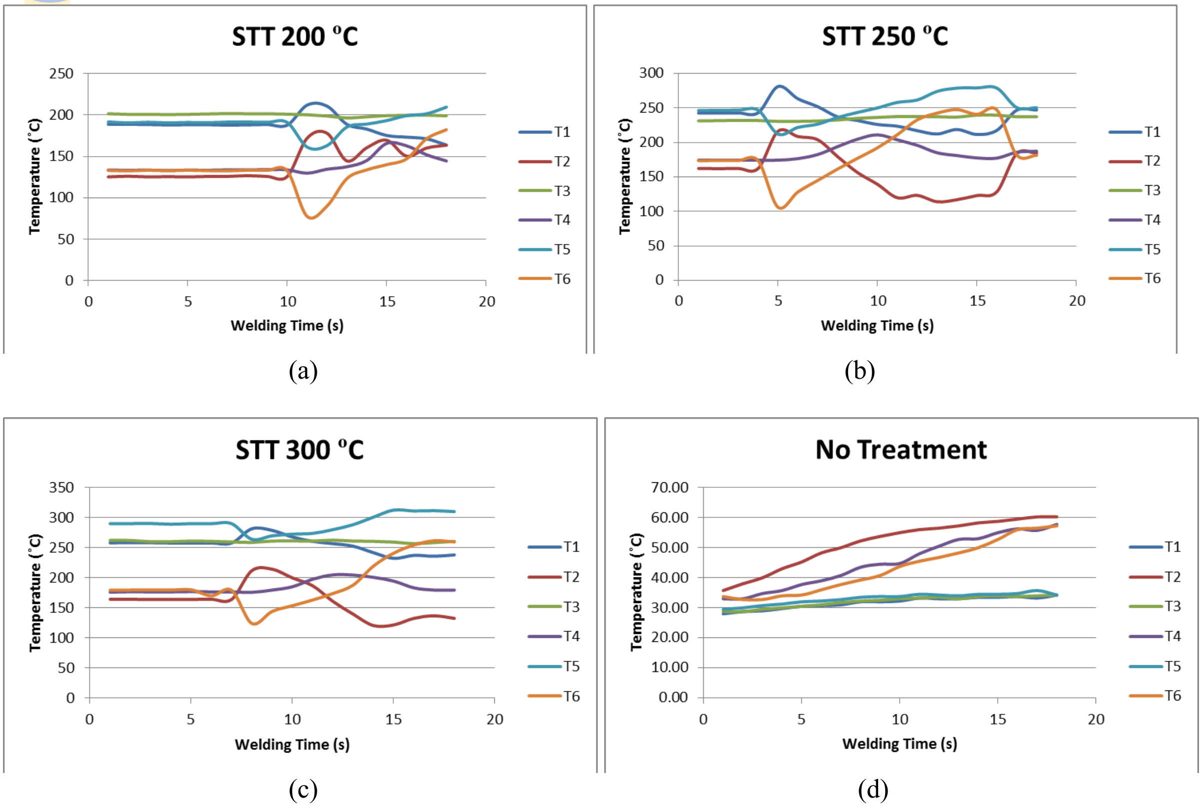


Figure 7. Distribution of Temperature During welding

From the welding process, the temperature from each thermocouple point is taken. It can be seen in Fig 7., when the heater temperature in the static thermal tensioning treatment is high, the temperature at the base metal is high too (T1, T3, T5). This behavior due to accumulation of heat that occurs in the welding area and the base metal. This behavior different in without treatment welding where the heat source is only found in the welding process, so heat accumulation wasn't high as static thermal tensioning method.

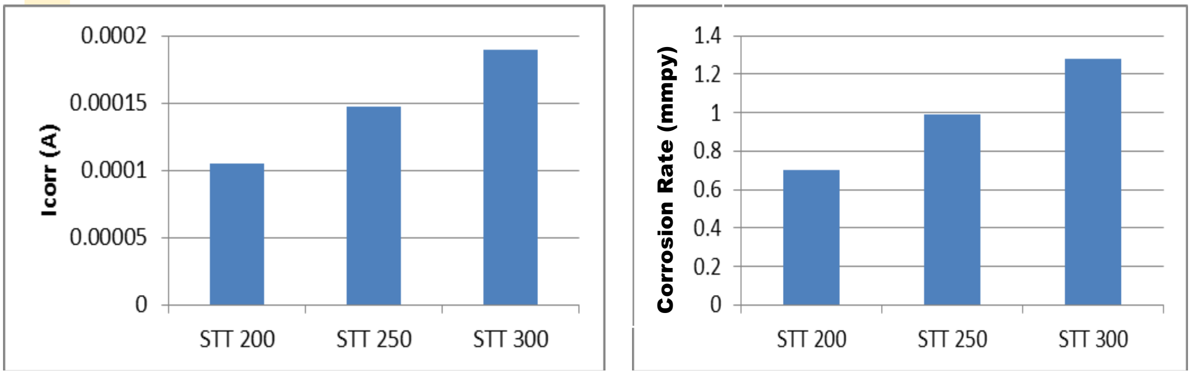
3.2 Corrosion Rate

The results of the measurement of corrotion rate on the SUS 304 plate from GMAW welding with T joints are presented in Table 2.

Table 2. Corrosion Rate of Static Thermal Tensioning Treatment with Temperature Variation

Treatment	ba(V)	bc(V)	jcorr (A/cm²)	icorr (A)	Corrosion rate (mm/year)	Polarization resistance (Ω)
No Treatment	0,17489	1,7783	9,15x10^{-5}	0,000183	1,2312	377,77
STT 200˚C	0,17589	0,80223	5,23x10^{-5}	0,000105	0,70303	599,36
STT 250˚C	0,2003	2,4682	7,38x10-^{5}	0,000148	0,99271	545,13
STT 300˚C	0,19609	1,6737	9,50x10^{-5}	0,00019	1,2773	401,41

In Fig 8. It is shown that the corrosion rate increases with increasing heater temperature in the static thermal tensioning treatment. The highest corrosion rate value is 1.2773 mm/year at temperature of 300˚C. While the lowest corrosion rate found at temperature of 200˚C with value of 0.70303 mm/year. The value of the corrosion rate (b) is closely related to the corrosion current (a) that occurs in the polarization of the potentiostat. This is because the corrosion process in metals is a spontaneous occurrence that takes place simultaneously with the presence of electrons flowing in the metal. the amount of electron flow is proportional to the height of the electric current. If the electric current increases, the corrosion rate also increases [14].



(A) (B)

Figure 8. Distribution of Temperature During welding

3.3 Residual Stress

The results of residual stress measurement according to the closest strain value from strain gage on the SUS 304 plate with T-Joint GMAW welding are presented in table 3.

Table 3. Residual Stress of Static Thermal Tensioning Treatment with Temperature Variation

Treatment	Young Modulus (MPa or N/mm2)	Micro Strain ($\mu\varepsilon$)	Stress (MPa)
No Treatment	187500	654.572963	122.7324306
STT 200 ˚C	187500	606.8958095	113.7929643
STT 250 ˚C	187500	563.6116825	105.6771905
STT 300 ˚C	187500	415.05	77.821875

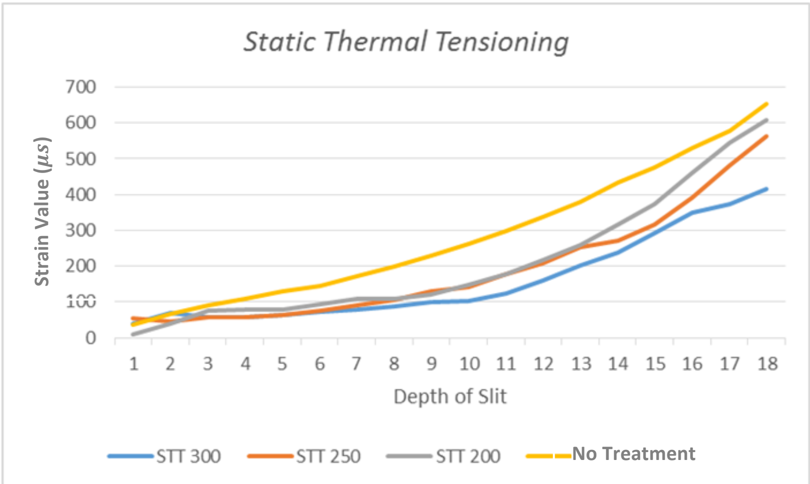


Figure 9. Strain Value Comparasion

According to the graph in Fig 9. when the cutting process on the specimen is deeper, the strain value is greater. The temperature of the static thermal tensioning treatment also affects the strain value. When heater temperature in the static thermal tensioning treatment is higher, the strain value in the cutting path also high. This is directly proportional to the residual stress value.

In Table. 3 it can be seen that the static thermal tensioning treatment at temperature of 200˚C has a stress value of 113.79Mpa, but it still lower than the without treatment welding method with value 122.73 Mpa. While the static thermal tensioning treatment at a temperature of 300˚C has the lowest stress value, which is 77.82 MPa. This is happen because the temperature difference between the base metal and the metal being welded is proportionally distributed, considering that the residual stress occurs due to unproportionally distribution of heat. Proportional heat distribution relief stress slowly [15].

4. CONCLUSION

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

1. The most optimal temperature from static thermal tensioning treatment to reduce corrosion rate on 5 mm thickness of SUS 304 T-Join welding is at 200˚C with 0.7 mm/year corrosion rate.
2. The most optimal temperature from static thermal tensioning treatment to reduce residual stress on 5 mm thickness of SUS 304 T-Join welding is at 300˚C with 77.8 MPa residual stress.
3. Correlation between corrosion rate and residual stress is inversely proportional even though they are both affected by the treatment temperature

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