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Effect of Transient Flame Static Tensioning Method on Distortion and Mechanical Properties of Aluminum A5083 with MIG Welding

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Abstract. This study aims to discover the best flame temperature in the Transient Flame Static Tensioning method. The used flame temperatures in this study are 100ºC, 200ºC and 300ºC. The minimum distortion is performed by utilizing a flame temperature of 200ºC, 300ºC and 100ºC. The tensile strength in the flame temperature variation of 100ºC, 200ºC, and 300ºC is 231.197 Mpa, 169,658 Mpa, and 156.729 Mpa respectively. The highest hardness of the base metal is at a flame temperature specimen of 100ºC with a value of 10.1321 kg/mm^2. The highest hardness in the HAZ area is at a flame temperature variation of 300ºC with a value of 15.9812 kg/mm^2. The highest hardness of the welding metal area is at a flame temperature variation of 300ºC with a value of 12.5805 kg/mm^2. Thus, 200ºC provides the ideal temperature for welding. The temperature distribution in this study indicates that higher heat input affects higher temperature around the welding area and vice versa. The provision of static cooling is to reduce the peak temperature around the welding despite insignificant results.

INTRODUCTION

Aluminum alloy is a non-ferrous metal, widely applied in various industries. The AA 5083 series wrought aluminum alloy is the commonly used type in welding construction of ships, high-speed ships, pressure vessels on ships and hull plates. Welding metal that is often used on aluminum metal type of AA5083 is MIG (Metal Inert Gas), which is suitable for thin plates utilized on ships to reduce the weight of the ship. In welding, a thermal cycle will occur resulting in residual stresses, distortion, and cooling rates in the welded metal and the surrounding area, especially on thin plates. In the end, the residual stress and the microstructure of the welded metal will affect the mechanical properties of the welded metal [1]. Several methods have been developed to eliminate the residual stresses and distortions to improve the mechanical properties of welded joints, one of which is thermal tensioning, by applying local heat around the weld line during the welding process [2] .

The thermal tensioning method has two types of methods, which are the static thermal tensioning (STT) method and the transient thermal tensioning (TTT) method [3]. The static thermal tensioning (STT) method serves as one way to reduce distortion by providing a source of heat and coolant during the welding process [4]. The transient thermal tensioning (TTT) method is utilized to provide a thermal tensile stress, thereby reducing the residual stress, in which during welding, local heat is applied to the area around the welding line by using a moving heat source [5].

Prior studies have been conducted to observe the STT and TTT methods in welding in order to minimize distortion and improve the mechanical properties of the material, despite less-optimal results [6][7]. Therefore, this research proposes the Transient Flame Static Tensioning method for better outcome. The working material used is Aluminum A5083 with MIG (Metal Inert Gas) welding.

METHOD

The method used in this study is the Transient Flame Static Tensioning method, enabling the provision of heat and cooling during the welding process to reduce the impact of residual stresses that occur during welding minimizing distortion. This study applies the three variations of flame temperature, which are 100ºC, 200ºC and 300ºC with ordinary water cooling. The result of this method is to discover the temperature distribution,

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distortion value and the best mechanical properties of the specimen from the three variations of flame temperature.

Tools and Materials

The tools used in this study include milling machines, semi-auto welding machines, inverters, static cooling pipes, water pumps, thermocouples, labview devices, flat tables, dial indicators, tensile testing machines and hardness testing machines. The materials used in this study include Aluminum A5083, argon gas, type 5356 electrode, oxygen gas, LPG gas, water, resin, catalyst and sandpaper.

Research Procedure

The making of welding specimens is conducted by using an automatic cutting machine, conducted in Surabaya. The size of the welding specimen is 350 mm long and 120 mm wide. The step is further conducted to make an open V-helmet, using a milling machine tilted up to an angle of 45º. The specimen is clamped on the chuck to continue the seam making process. Prior to the welding process, it is necessary to prepare the parameters including those as illustrated in Table 1.

TABLE 1. Welding Parameters

Sample	Current (A)	Water Debit (L / hour)	Flame Temperature (ºC)	Flame Distance (mm)	Welding Speed (mm/s)
1	100	1400	100	80	10
2	100	1400	200	80	10
3	100	1400	300	80	10

When performing welding, the required tool of MIG is prepared, further drilling the plate in the specified section for the installation of the thermocouple. The thermocouple cable is later attached to the plate using nuts and bolts. Afterwards, the thermocouple cable has been connected to the computer, by placing the 2 cooling channels under the plate to be welded, by setting the desired welding speed by programming on the inventor and adjusting the distance and angle of the welding torch with the workpiece to be welded as desired. Further, the process is continued to open the protective gas valve on the tube and to adjust the welding current and electrode speed. The process is progressed by placing a negative current on the body of the welding tool. The distance is later adjusted between the heating torch and the workpiece according to the desired distance, continued by setting the hot flame for specimen 1 of 100ºC, specimen 2 of 200ºC and specimen 3 of 300ºC. The heating temperature is measured by using a thermocouple according to the desired temperatures of 100ºC, 200ºC and 300ºC. The water pump is set as the coolant passing through the pipe. If the previous steps have been set, the next step is conducted by clicking the start button to start the welding. When the welding length is reached, the process is finalized by pressing the stop button to stop welding.

Material Test

The first test includes the observation of the temperature distribution. Observation of the temperature distribution is conducted to determine the heat level that occurs during the welding process. The next test is continued with the distortion test to make a line on the plate with a distance of 1 cm wide and 2 cm long which covers the surface. Clamp on both sides of the plate is conducted by using a special tool, conducted on a flat table to calibrate the lowest point on the plate surface using a dial indicator. Measurement on each line records the distortion values obtained using the dial indicator.

After the distortion test is completed, the tensile test is continued in the tensile test utilizing ASTM E8. Calculations in the tensile test are performed using Equation 1, Equation 2, and Equation 3.

$$max = \frac{P_{max}}{(w_0 \times t_0)} \tag{1}$$

$$yield = \frac{P_{yield}}{(w_0 \times t_0)} \tag{2}$$

$$\frac{\Delta_L}{L_0} \times 100\% \tag{3}$$

The next test is continued with a hardness test, by utilizing the Vickers method performed on the surface of the material from the base metal area, HAZ and welding area. In the hardness test, Equation 4 is applied.

$$VHN = (1.855) \times \frac{p}{d^2} \tag{4}$$

RESULTS AND DISCUSSION

The welded specimen will then enter the testing phases, comprising observation of temperature distribution, distortion test, tensile test and hardness test. The results of the tests carried out will then be discussed.

Observation of Temperature Distribution

Observation of the temperature distribution in welding is conducted to determine the heat level that occurs during the welding process. Thermocouple 1 (TC1) is located at 5 mm from the welding line, thermocouple 2 (TC2) is located at 25 mm from the welding line, thermocouple 3 (TC3) is located at 50 mm from the welding line and thermocouple 4 is located at 80 mm from the welding line. The following Figure 1 illustrates the temperature during the welding process.

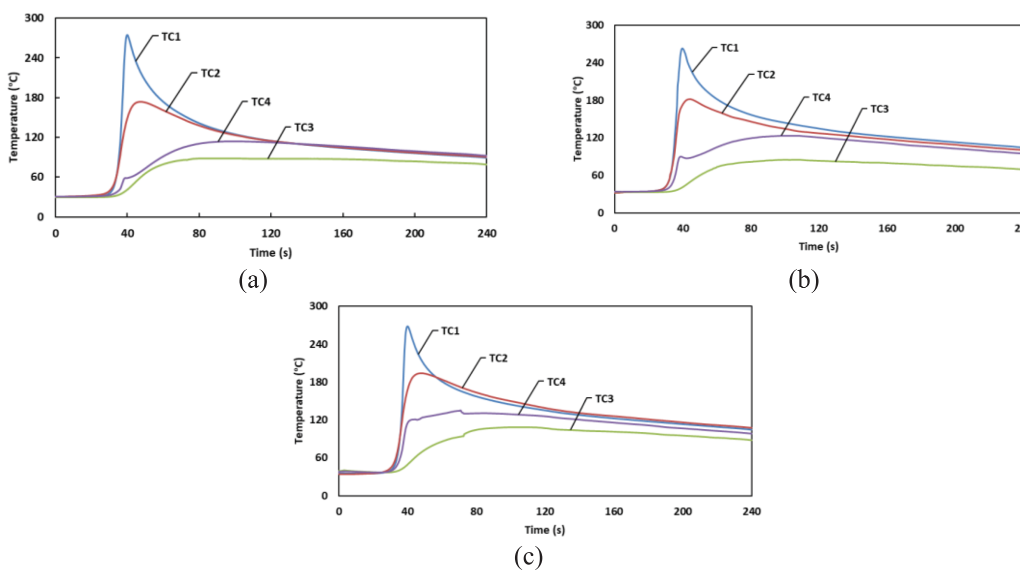

FIGURE 1. Effect of Time on Temperature in MIG Welding Utilizing Flame Temperature (a) 100ºC, (b) 200ºC, and (c) 300ºC

In Figure 1(a), a specimen with a flame temperature of 100ºC indicates that the highest heat in thermocouple 2 (TC2) reaches a temperature of 173ºC. In Figure 1(b), a specimen with a flame temperature of 200ºC reaches the highest heat in thermocouple 2 (TC2) of 182ºC. In FIGURE 1(c) the specimen with a flame temperature of 300ºC reaches the highest heat in thermocouple 2 (TC2) of 193ºC. The three illustrations indicate that the increasing flame temperature affects the temperature distribution during the welding process.[8]

At TC1 in each image, it is evident that there is a fast-cooling rate, due to the placement of static cooling under the plate adjacent to TC1, in 20 seconds after the peak heat decreases in each specimen. The temperature of the specimen with a flame temperature of 100ºC decreases by 101ºC then the specimen with a flame temperature of 200ºC decreases by 82ºC and the specimen with a flame temperature of 300ºC decreases by 87ºC. Thus, the best cooling rate lies in the specimen with a flame temperature of 100ºC, indicated from the shape of the image on TC1 after reaching the peak temperature, then the temperature drops steeply due to rapid cooling (quenching).[9]

Distortion Test

Distortion is a change in shape caused by heat, due to the welding process. This distortion test aims to discover the difference in the distortion results from the three different flame temperature variations. The following is a 3D image of the distortion from the three flame temperature variations.

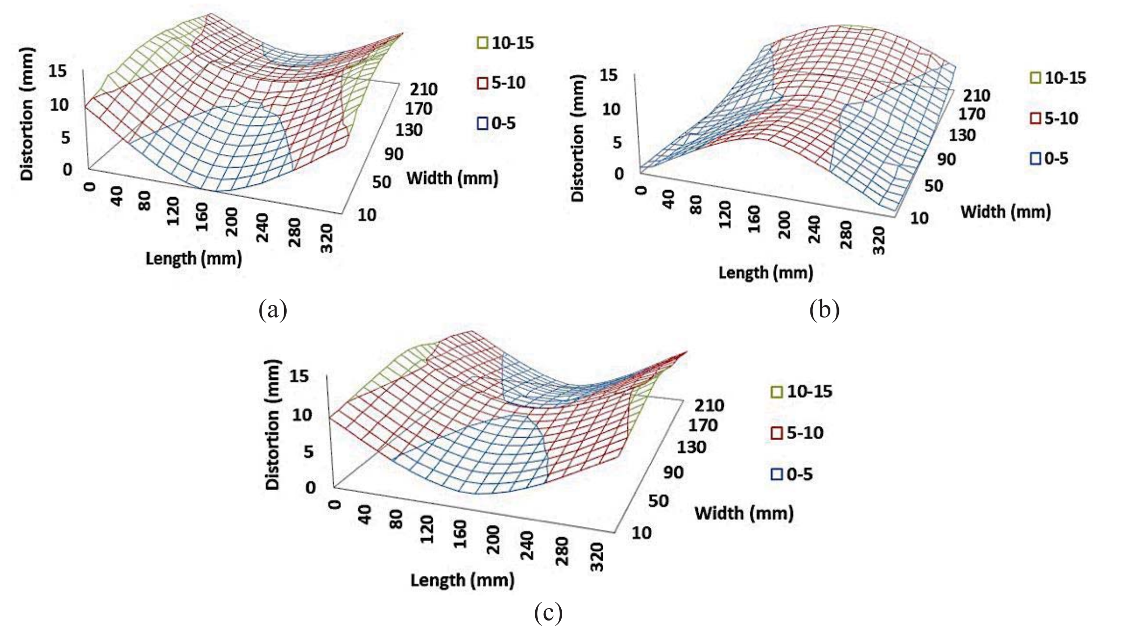

FIGURE 2. 3D Distortion Graph with Flame Temperature (a) 100ºC, (b) 200ºC, and (c) 300ºC

Referring to Figure 2(a), (b), and (c), it is apparent that each specimen has a different distortion value. In the 3D graph for specimens using a flame temperature of 100ºC, the highest distortion value is 12.78 mm. Then on the 3D graph for specimens using a flame temperature of 200ºC, the highest distortion value is 10.28 mm. In the 3D graph for specimens using a flame temperature of 300ºC, the highest distortion value is 11.81 mm. The following presents a comparison graph of the longitudinal distortion of specimens at flame temperatures of 100ºC, 200ºC and 300ºC based on the three different lines.

Thus, the smallest distortion is produced by the flame temperature of 200ºC, indicating that the provision of transient thermal during the welding affects the difference in distortion on the plate. This finding is in accordance with a prior study conducted by Yunaidi (2013). Transient Thermal Tensioning could reduce the distortion that occurs due to the welding process [2].

Hardness Test

The hardness testing is conducted by applying the Vickers Hardness Number method with a load of 1 kg. The number of tests is three times from each base metal area, HAZ and welding area to obtain the average value. Figure 3 indicates the results of the hardness test.

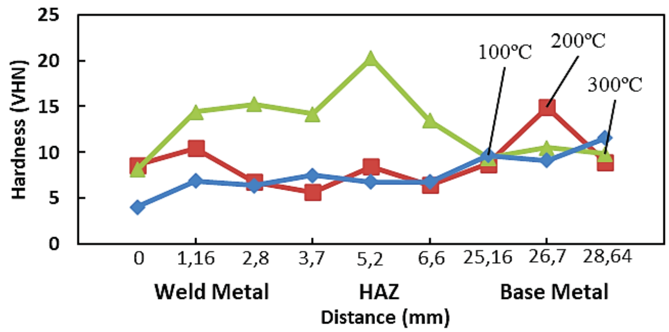

FIGURE 3. Relationship of Specimen Hardness to Point Distance

From the presented data, it is obvious that the highest average hardness of the specimen with a temperature of 100ºC is located in the base metal area with a value of 10.1321 kg/mm^2. Further, the second highest is in the HAZ area with a value of 7.0374 kg/mm^2 and the last is in the metal area with a value of 5.7898 kg/mm^2. Meanwhile, the highest average hardness of the specimen with a temperature of 200ºC is located in the base metal area with a value of 10.8584 kg/mm^2. Later, the second highest is in the metal area with a value of 8.6148 kg/mm^2 and the last is in the HAZ area with a value of 6.8619 kg/mm2. Furthermore, the highest average hardness of the specimen with a temperature of 300ºC is located in the HAZ area with a value of 15.9812 kg/mm^2. Then the second highest is located in the metal area with a value of 12.

From the three variations of flame temperature, the highest average hardness value is located in the base metal area where there is a fast-cooling rate due to the presence of cooling, generating a fine microstructure [8]. In the base metal, the highest hardness is found in the specimen with a flame temperature of 100ºC. As the flame temperature increases, the hardness decreases too [10].

CONCLUSION

This study concludes that the high heat input affects the high temperature around the welding area and vice versa from the observation of the temperature distribution. The provision of static cooling can reduce the peak temperature around the welding, although it is insignificant. The use of the Transient Flame Static Tensioning method in the MIG welding process using a flame temperature of 200ºC is better in reducing distortion than with other temperature variations. The highest average hardness in the base metal area lies in the flame temperature specimen of 100ºC with a value of 10.1321 kg/mm^2. The highest average hardness in the HAZ area is located at the flame temperature specimen of 300ºC with a value of 15.9812 kg/mm^2. Furthermore, the highest average hardness in the metal area is located at a flame temperature specimen of 300ºC with a value of 12.

REFERENCES

1. Jufri, M. and A. Asfat. "Efek Kecepatan Pengelasan Terhadap Sifat Mekanik Hasil Pengelasan Fcaw Pada Plat Baja A36". in Prosiding SENTRA (Seminar Teknologi dan Rekayasa). (2017).
2. Yunaidi, M.N.I., "Pengaruh Preheat dan Thermal Tensioning Terhadap Sifat Fisis dan Mekanik pada Sambungan Las TIG Al 6061-T6". Fakultas Teknik, Universitas Gadjah Mada, Yogyakarta, 7, (2013).
3. M. Mochizuki and M. Toyoda, "Weld Distortion Control During Welding Process With Reverse-Side Heating," J. Eng. mater. Technol., **129**, 265–270 (2007).
4. N. Subeki, Jamasri, MN Ilman, and PT Iswanto, "The Influence of Preheat on Distortion and Fatigue Crack Propagation Rate of FCAW Weld in A 36 Steel Structure," Appl. mech. mater. **842**, 83–91 (2016).
5. Sahata, E. And M.N. Ilman, "Pengaruh Perlakuan Transient Thermal Tensioning Terhadap Sifat Mekanis Dan Fatik Pada Sambungan Las Fsw Aluminium Seri 5083," Universitas Gadjah Mada (2014).
6. MN Ilman, Kusmono, and PT Iswanto, "Fatigue crack growth rate behaviour of friction-stir aluminium alloy AA2024-T3 welds under transient thermal tensioning," Mater. Dec. **50**, 235–243 (2013).

7. MN Ilman, Kusmono, MR Muslih, N. Subeki, and H. Wibowo, “Mitigating distortion and residual stress by static thermal tensioning to improve fatigue crack growth performance of MIG AA5083 welds,” Mater. Dec. **99**, 273–283 (2016).
8. N Subeki, T.Jamasri., M.N. Ilman, P.T. Iswanto, “Minimizing Distortion by Transient Thermal Tensioning and Its Effect on Fatigue Crack Growth Behavior of Flux Cored Arc Steel Weld Joints,” International Journal of Engineering and Technology (IJET), **9**, 8 (2017).
9. Ilman, M., Muslih, MR, Subeki, N, Wibowo, H, “Mitigating distortion and residual stress by static thermal tensioning to improve fatigue crack growth performance of MIG AA5083 welding,” Materials & Design, **99**, 273-283 (2016).
10. Cai C, Wang X, Liang Z, Rao Y, Wang H, Yan D. “Effects of water-cooling on the mechanical properties and microstructure of 5083 aluminum alloy during flame straightening. Metals (Basel),” **8**, (2018).