Evaluation of Mechanical Properties of SS 316 L Using Constant Heat Treatment of Welding Tungsten Gas Arc (GTAW)

Duwi Leksono Edy1\*, Heru Suryanto2, Imam Sudjono3

1Mechanical Engineering Department, Universitas Negeri Malang, Jl. Semarang 05, Malang, Indonesia

2Mechanical Engineering Department, Universitas Negeri Malang, Jl. Semarang 05, Malang, Indonesia

3Mechanical Engineering Department, Universitas Negeri Malang, Jl. Semarang 05, Malang, Indonesia

*\*Corresponding author:duwi.leksono.ft@um.ac.id*

|  |
| --- |
| ABSTRACT |
| SS 316L material is stainless steel which has been widely used in the industrial world both in petroleum, gas distribution and in manufacturing. SS 316L material has good corrosion resistance and mechanical properties. In addition, SS 316 L is also more desirable because the price is cheaper than duplex or superduplex stainless steels. Stainless steel must also have good weldability, because welding is a very important process in manufacturing. The use of SS 316 L more in the manufacturing process, especially in the oil field, is the basis for evaluating the extent of changes in the characteristics of SS 316 L steel after welding with several treatments.The welding process works to see the changing mechanical properties of the metal after the welding process is carried out using a constant temperature. Welding process using Gas Tungsten Arc Welding (GTAW) welding. Constant heating to maintain the heating temperature by using Micro Heating on the surface of the welding process.The results of the treatment with a comparison of the average value of a constant temperature of 100 ℃ the average hardness value of 115.6 HVN, a constant temperature of 120 ℃ an average hardness value of 131.0 HVN, and a constant temperature of 140 ℃ of an average hardness value of 171.5 HVN. Anova test shows that the influence of heating temperature on the hardness level of SS 316 L material has a value of Fcount = 201.690 while the value of sig. = 0,000, while the value (sig) is smaller than the significance level of the study, which is α = 0.05. This means that the alternative hypothesis influences the level of hardness of the metal with constant heating on the welding surface of GTAW. |
| ***Keywords:*** *SS 316 L steel, Gas Tungsten Arc Welding (GTAW), Heat Treadment.* |

1. **Introduction**

SS 316L material is stainless steel which has been widely used in the oil, gas and manufacturing industries. In the welding process of SS316L material, the welding heat melts the surface end of the welded parent metal together with the fused metal fusion resulting in changes in the microstructure in the weld area and its surroundings as well as having an impact on the mechanical and geometrical properties of the weld metal [1]. Factors that influence the mechanical properties of welds are influenced by the chemical composition of welds and the microstructure that is formed. The microstructure and hardness of the welding results in the HAZ region are highly dependent on the cooling rate, where the cooling rate is influenced by several factors namely plate thickness, welding conditions, preheat, heat input and the environment [2].

Heat input is one parameter that contributes to distortion and residual stress. The more welding layers increase the greater the distortion. On thin plates, distortion often occurs which results in undesirable dimensions of dimension changes. But on thick plates with a broad cross section, distortion is not visible but the residual stress that is formed is very large if a measurement is made. The deformation of the weld geometry occurs due to local heating with the welding heat source where the temperature distribution is uneven and changes, as well as changes in welding speed [3].

Excessive heat input can reduce ferrite content [4]. High heat causes the material to be at peak temperature which causes the growth of grains which will affect its mechanical properties [5]. The amount of heat input that is different in the welding process will produce different mechanical properties and shapes of welds. If the heat input is high enough, the cooling rate will be slower. Slow cooling rate, ferrite-austenite transformation occurs with sufficient time. An adequate cooling rate can result in the formation of austenite which is stable, but also to prevent the formation of precipitation. The heat input control in the welding process is very important and needs to be considered to produce good microstructure and mechanical properties.

1. **Material and Method**

Observations in this study using SS 316 L material with the treatment of maintaining the heat temperature of the welding process. The welding process of SS 316 L material with the welding joint model uses a single V seam with a seam angle of 60o, root gap 2 mm, root face 1 mm at 5mm object thickness. The work on making specimens which include cutting material, making the seam is done by cold working, it aims to not change the mechanical properties of the SS 316 L material due to the influence of heat that arises when the working process occurs. For the size and shape of the specimen using the standard specified ASTM E8 / E8M-09.



Figure 1. Size of weld seam

The chemical composition of SS 316 L material in this study can be described as follows:

Table 1. Chemical Composition of 316 stainless Steel.

| **Elements** | **Weight Percentage** |
| --- | --- |
| Weight percentage | 0.08 |
| Manganese | 2.00 |
| Sulphar | 0.030 |
| Silicon | 0.75 |
| Nitrogen | 0.10 |
| Phosphorus | 0.045 |
| Chromium | 16.0-18.0 |
| Nitrogen | 0.10 |
| Nickel | 10.0-14.0 |
| Molybdenum | 2.0-3.0 |

The material specifications are

Material : 316 Austenitic stainless steel

Thickness : 3 mm

Length : 100mm

Number of samples : 27

1. **Results and Discussions**

The results of the heating treatment in the heating welding process with constant temperature variations in the GTAW welding, then obtained.



Figure 2. GTAW welding results with a constant temperature of 100 ℃



Figure 3. GTAW welding results with a constant temperature of 120℃



Figure 4. GTAW welding results with a constant temperature of 140℃

**Vickers Hardness Test**

Hardness test uses the Vickers method. Hardness test was carried out in the HAZ area, each sample of seven points in each treatment to obtain an average hardness value. The results of the hardness test are shown in Table 2.

**Constant temperature of 100 ℃**

Following are the hardness testing data of Vickers at a constant temperature treatment of 100 ℃.

Table 2. Vickers hardness test results on GTAW welding results with a constant temperature of 100 ℃.

|  |  |  |  |
| --- | --- | --- | --- |
| **Heating Temperature** | **Sample** | **Test Point** | **Hardness Test (VHN)** |
| 100℃ | HAZ | 1 | 112,5 |
|  |  | 2 | 118,6 |
|  |  | 3 | 104,6 |
|  |  | 4 | 116,8 |
|  |  | 5 | 114,4 |
|  |  | 6 | 122,3 |
|  |  | 7 | 120,8 |
| Mean |  |  | 115,6 |

**Constant temperature of 120 ℃**

Following are the hardness testing data of Vickers at a constant temperature treatment of 120 ℃.

Table 3. Vickers hardness test results on GTAW welding results with a constant temperature of 120 ℃.

|  |  |  |  |
| --- | --- | --- | --- |
| **Heating Temperature** | **Sample** | **Test Point** | **Hardness Test (VHN)** |
| 120℃ | HAZ | 1 | 132,6 |
|  |  | 2 | 137,9 |
|  |  | 3 | 129,6 |
|  |  | 4 | 131,7 |
|  |  | 5 | 134,7 |
|  |  | 6 | 130,3 |
|  |  | 7 | 120,8 |
| Mean |  |  | 131.0 |

**Constant temperature of 140 ℃**

Following are the hardness testing data of Vickers at a constant temperature treatment of 140 ℃.

Table 4. Vickers hardness test results on GTAW welding results with a constant temperature of 140 ℃.

| **Heating Temperature** | **Sample** | **Test Point** | **Hardness Test (VHN)** |
| --- | --- | --- | --- |
| 140℃ | HAZ | 1 | 165,8 |
|  |  | 2 | 175,5 |
|  |  | 3 | 170,3 |
|  |  | 4 | 167,4 |
|  |  | 5 | 174,6 |
|  |  | 6 | 178,3 |
|  |  | 7 | 168,8 |
| Mean |  |  | 171.5 |

**Hardness Test Data Analysis**

As for seeing more clearly the results of the vickers hardness test on each specimen with a constant temperature difference in the welding process 100 ℃, 120 ℃, and 140 ℃ then this study will describe the results of vickers hardness test using ANOVA analysis to distinguish the level of hardness of each specimen. The following are the results of the vickers hardness test for each specimen described through the ANOVA analysis results.

| Table 5.Test of Homogeneity of Variances |
| --- |
| Hardness Test Results |  |  |
| Levene Statistic | df1 | df2 | Sig. |
| .137 | 2 | 18 | .873 |

| Table 6. **ANOVA** |
| --- |
| Hardness Test Results |  |  |  |  |
|  | Sum of Squares | df | Mean Square | F | Sig. |
| Between Groups | 11666.000 | 2 | 5833.000 | 201.690 | .000 |
| Within Groups | 520.571 | 18 | 28.921 |  |  |
| Total | 12186.571 | 20 |  |  |  |

Data in the hardness test results table using Vickers can be seen in all specimens that there are differences in the level of violence in the HAZ area. The results can be seen in the comparison of the average value of constant temperature 100 ℃ the average hardness value of 115.6 HVN, the constant temperature of 120 ℃ the average hardness value of 131.0 HVN, and the constant temperature of 140 ℃ of the average hardness value of 171.5 HVN. The higher the constant temperature applied to the steel carried out the welding has good hardness. Good cooling rate that affects the mechanical strength of the welding results. In this GTAW welding many factors must be considered such as heat input, cooling rate and the material to be welded [6]. The ongoing heat transformation at HAZ changes gradually from the parent metal structure to the weld metal structure [7].

Anova test results show that the influence of heating temperature on the hardness level of SS 316 L material has a value of Fcount = 201.690 while the value of sig. = 0,000, while the value (sig) is smaller than the significance level of the study, which is α = 0.05. So it can be concluded that H0 is rejected and H1 is accepted. This means that the alternative hypothesis is that there is a difference in the level of constant heating temperature on the GTAW welding surface to the level of hardness of the welding results accepted with a significance level of 5%.

1. **Conclution**

The welding process is influenced by the rate of cooling on the metal surface, this affects the formation of metal structures during the cooling process. This can be seen from the trial by maintaining a constant temperature of the surface of the welding table with temperatures of 100 ℃, 120 ℃, 140 ℃ where each machine produces a different hardness strength. Hardness is most effective at a constant temperature of 140 ℃ because the temperature at the GTAW welding surface is maintained.

1. **Acknowledgmen**

The welding process is influenced by the rate of cooling on the metal surface, this affects the formation of metal structures during the cooling process. This can be seen from the trial by maintaining a constant temperature of the surface of the welding metal with temperatures of 100 ℃, 120 ℃, 140 ℃ where each machine produces a different hardness strength. Hardness is most effective at a constant temperature of 140 ℃ because the temperature at the GTAW welding surface is maintained.

1. **Reference**

|  |  |
| --- | --- |
| [1] | Huang, H.Y., Shyu, S.W., Tseng, K.H., & Chou, C.P. (2006). Study of the process parameters on austenitic stainless steel by TIG-flux welding. Journal of Material Science and Technology 22, 8, 367-374. |
| [2] | Lippold, J.C., Damian, J.K. (2005). Welding metallurgy and weldability of stainless steel. Wiley-Interscience Publication |
| [3] | Burgardt, P., & Heiple, C.R. (1986). Interaction between impurities and welding variables in determining GTA weld shape. Welding Journal 65, 6, 150-155. |
| [4] | Arif, F.S. (2012). Perbedaan karakteristik hasil pengelasan metode GTAW dan SMAW terhadap baja tahan karat 316L. Tesis, Program Sarjana Universitas Indonesia, Depok |
| [5] | Arivazhagan, B., Srinivasan, G., Albert, S.K., & Bhaduri, A.K. (2011). A study on influence of heat input variation on microstructure of reduced ferritic martensitic steel weld metal produced by GTAW process. Journal of Fusion Engineering and Design 86, 6, 192-197. |
| [6] | Konadi, E., & Fhatier, N. (2018). Pengaruh Suhu Preheat Terhadap Ketangguhan Baja Aisi 1050 Pada Proses Pengelasan. 2(1), 102–104. |
| [7] | Wiryosunarto Harsono, Toshie Okumura.(2000).“Teknologi Pengelasan Logam”, Cetakan Kedelapan, Pradnya Paramita, Jakarta. |