

The Effect of Post Welding Heat Treatment/PWHT on the Corrosion Rate of Welded AISI 1020 Steel in a Marine Environment of the Northern Area of Semarang, Jawa Tengah, Indonesia

^{1*}Agus Suprihanto, ²Dwi Basuki Wibowo

^{1,2}Mechanical Engineering Department, Faculty of Engineering, Diponegoro University, Jl. Prof. H. Soedarto, SH, Tembalang-Semarang 50275, Indonesia

*Corresponding Author's E-mail: agusm90@yahoo.com

Abstract - AISI 1020 steel is widely used in construction, where its assembly requires Shielded Metal Arc Welding (SMAW). The welding process leads to a decrease in its corrosion resistance properties. To overcome this issue, the Post Weld Heat Treatment (PWHT) method has been developed to improve its corrosion resistance. The welding process utilizes the Shielded Metal Arc Welding (SMAW) method with process parameters such as a butt joint connection type, a current strength of 60, voltage ranging from 20-26 V, and RD460 welding electrode. The conducted tests include microstructure testing, hardness testing, and wear resistance testing in seawater. Post Weld Heat Treatment (PWHT) is carried out at temperatures of 400, 500, and 600 °C, with holding times of 1, 2, and 3 hours. The test results indicate that higher temperatures and holding times result in a more homogeneous microstructure, decreased hardness, and lower corrosion rates. The reduction in corrosion rates is attributed to the increasing homogeneity of the microstructure and the decrease in residual stress.

Keywords: AISI 1020, SMAW, PWHT, Corrosion Rate.

I. INTRODUCTION

The northern coastal area of the city of Semarang in Central Java, Indonesia, is an important region for the national economy. Many warehouses, factories, and docks are constructed in this area. The existing structures include many that utilize construction made of steel. One type of steel commonly used is low-carbon steel, namely AISI 1020.

AISI 1020 steel is a low-carbon steel with high tensile strength and ductility [1]. Due to its low carbon content, this steel exhibits good weldability [2]. Therefore, it is widely used as a material for constructing steel structures. As known, the assembly of structural components often requires joining through welding processes.

The common welding process method used in connecting structural elements is Shielded Metal Arc Welding (SMAW). SMAW welding uses heat from electricity to melt the metal, allowing it to be joined. The heat generated during the welding process causes a change in the microstructure of the steel and introduces residual stresses [3]. Both of these factors contribute to a decrease in corrosion resistance [4, 5].

Efforts to restore corrosion resistance typically involve performing Post Weld Heat Treatment (PWHT) [6, 7]. The principle behind this treatment is to reheat the welded steel to a specific temperature for a certain duration. The primary goal of PWHT is to improve the microstructure and eliminate residual stresses. This study explores the effect of the PWHT process on the welding of AISI 1020 steel regarding the corrosion rate in seawater.

II. RESEARCH METHOD

AISI 1020 steel plate with a thickness of 3 mm is joined using Shielded Metal Arc Welding (SMAW). The welding process parameters include a current of 60 A, voltage ranging from 20-26V, and a welding speed of 48 mm/min. The welding electrode used is RD 460 with a 2mm diameter equivalent to AWS A5.1 E 6013. The welding position is 1G, and the joint type is a butt joint as shown in Figure 1.

The chemical composition of AISI 1020 steel from Atomic Absorption Spectrometer test is shown in Table 1 and the chemical composition of welding electrode is shown in Table 2. After the plate is welded, its surface is cleaned using a steel brush, and then the surface is flattened using a milling machine.

PWHT treatment is conducted using the EuroTerm furnace by adjusting the heating rate 10°C/minute. PWHT heating is performed at temperatures of 400, 500, and 600°C, with variations in holding time of 1, 2, and 4 hours. After

heating, the specimens are removed from the furnace and cooled in open air. Subsequently, plates that have undergone PWHT are prepared as specimens for microstructure observation and corrosion testing.

Table 1: Chemical composition of AISI 1020 (%wt)

C	Si	Mn	P	Fe
0.15 - 0.20	0.20 – 0.24	0.005	0.005	Balance

Table 2: Chemical composition of RD460 electrode (%wt)

C	Si	Mn	Mo	Cr	Ni	V	Fe
0.20	1.00	1.20	0.3	0.20	0.30	0.08	Balance

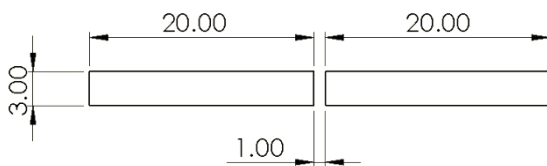


Figure 1: Join Design

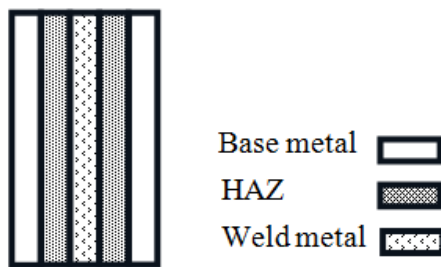


Figure 2: Schematic for corrosion test specimens which cover base metal, HAZ and Weld metal

Microstructure observation is carried out using an Olympus BX53M LOM. Microstructure observation aims to identify the morphology and phases present in the specimen before and after the PWHT process. Corrosion testing utilizes a Corrtest CS300 galvanostat. The corrosion testing procedure follows ASTM G59-97 standards. The corrosion test media involves seawater collected from Marina Beach, Semarang, Central Java, Indonesia. The corrosion test specimens are rectangle with 10mm and 20mm height and 3 mm thickness which is cover the base metal, HAZ, and weld metal, as illustrated in Figure 2.

III. RESULTS AND DISCUSSION

The microstructure of AISI 1020 steel plate before and after welding generally consists of ferrite and pearlite. This occurs because AISI 1020 steel is a low-carbon steel, and the phases in the microstructure do not undergo changes due to heat treatment [8]. However, in the Heat Affected Zone (HAZ), the grain size becomes coarser compared to the base metal. Grain coarsening in the HAZ can occur due to thermal

cycles during welding [9]. The high temperatures during welding have caused the mechanism of recrystallization and grain growth to take place.

The microstructure of weld metal shows there is more pearlite than base metal and HAZ. The microstructure in the weld metal region shows that the percentage of pearlite is higher than in the base metal and HAZ (Heat Affected Zone). This is because in the weld metal region, there has been a mixing of the chemical composition of the welding electrode with AISI 1020 steel. The microstructure of welded specimens before PWHT as shown in Figure 3.

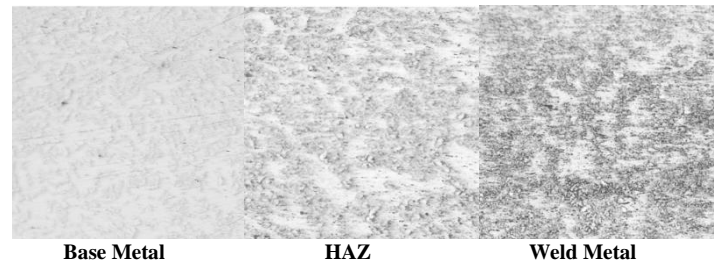


Figure 3: The microstructure of welded plate before PWHT consists of ferrite (bright) and pearlite (dark). Magnification 200X

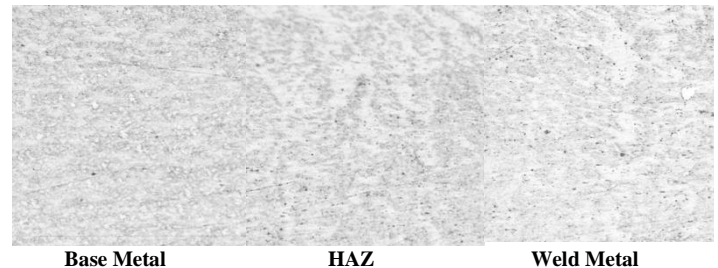


Figure 4: The microstructure of welded plate after PWHT consists of ferrite (bright) and pearlite (dark). Magnification 200X

The microstructure of the specimen after PWHT also consists of ferrite and pearlite. However, unlike before PWHT, the grain size for the base metal, HAZ, and weld metal areas is relatively uniform. Figure 4 show the typical microstructure of welded specimens after PWHT.

Steel plates are typically produced through hot rolling in the initial stages and finished with cold rolling to achieve the desired thickness dimensions [10]. The application of cold rolling in the final stage introduces residual stresses and deformation [11]. Therefore, when a high-temperature process like PWHT is performed, a recrystallization process and grain growth occurs. The temperature range for this process in low-carbon steel is generally between 400 and 700°C.

Figure 5 shows the Tafel plot of specimens before PWHT. From the three tested specimens, it can be observed that the Tafel plots vary significantly. This indicates that before PWHT, the microstructure is not homogeneous. Figure

6 illustrates the typical Tafel plot from three tested specimens after PWHT, showing less variation compared to before PWHT. This suggests that the microstructure of the specimens is relatively more homogeneous after PWHT.

The corrosion test results indicate that the higher the heating temperature, the lower the corrosion rate. Similarly, for the same heating temperature, the longer the holding time, the lower the corrosion rate as well. Table 3 shows the corrosion test results. Thus, PWHT treatment can improve corrosion resistance in low-carbon AISI 1020 steel welding.

From Table 3, it can be seen that for the same holding time, increasing the temperature decreases the corrosion rate. Similarly, for the same temperature, increasing the holding time reduces the corrosion rate. However, a longer holding time is not as effective in reducing the corrosion rate compared to temperature. In other words, higher heating temperatures produce a more significant reduction in the corrosion rate.

conditions, phases in the microstructure, and grain sizes. PWHT treatment has caused the microstructure in the base metal, HAZ, and weld metal areas to become generally more homogeneous compared to before PWHT. This increased microstructural homogeneity reduces the impact of corrosion attacks, leading to a decrease in the corrosion rate [12]. In other words, corrosion resistance of steels increases.

Another factor influencing corrosion attacks is the presence of residual stresses. Residual stresses cause a large energy field, making the metal susceptible to corrosion. Residual stresses commonly occur in the welding process due to thermal cycles during welding. Non-uniform expansion and contraction during the welding process are the main factors that create residual stresses in the welded area. To minimize residual stresses, stress relieving is generally performed [13]. The method used involves heating the metal to a high temperature for certain duration and then slowly cooling it. Factors affecting the effectiveness of stress relieving include heating temperature and holding time.

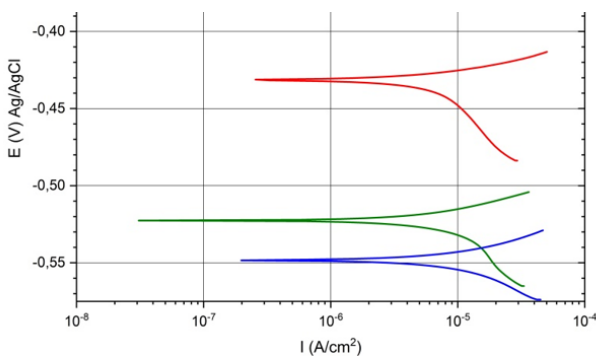


Figure 5: Typical Tafel Plot specimens before PWHT (Corrosion Test was conducted for 3 specimens)

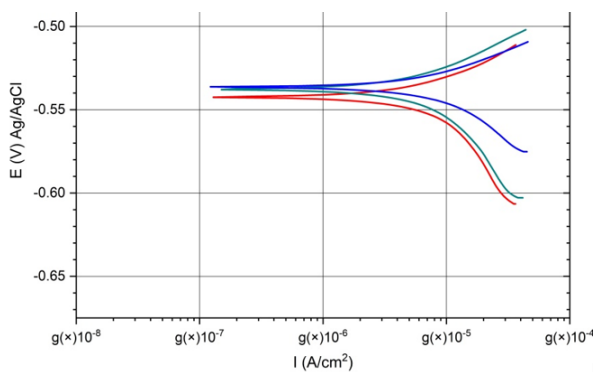


Figure 6: Typical Tafel Plot specimens after PWHT (Corrosion Test was conducted for 3 specimens)

As is known, corrosion attacks can occur in the presence of metal inhomogeneity. This inhomogeneity can be in the form of variations in chemical composition, heat treatment

Table 3: Corrosion rate welded AISI 1020 steel (mmy)

	Corrosion Test Specimens Number			Average
	1	2	3	
Before PWHT	0.092710	0.210240	0.217620	0.173523
PWHT at 400°C for 1hr	0.185840	0.154620	0.160470	0.166977
PWHT at 400°C for 2 hr	0.110410	0.214960	0.158010	0.161127
PWHT at 400°C for 4 hr	0.134320	0.060440	0.121170	0.105310
PWHT at 500°C for 1 hr	0.139200	0.108890	0.145870	0.131320
PWHT at 500°C for 2 hr	0.093120	0.127670	0.141700	0.120830
PWHT at 500°C for 4 hr	0.105840	0.062110	0.114230	0.094060
PWHT at 600°C for 1 hr	0.115710	0.140530	0.113740	0.123327
PWHT at 600°C for 2 hr	0.062460	0.105020	0.161080	0.109520
PWHT at 600°C for 4 hr	0.141160	0.040260	0.084340	0.088587

The principle of stress relieving treatment is identical to the PWHT process conducted in this study. Therefore, PWHT treatment not only improves the microstructure to become more homogeneous but also eliminates residual stresses. The combination of a more homogeneous microstructure and the elimination of residual stress results in a decrease in the corrosion rate or an increase in the corrosion resistance of AISI 1020 steel [12].

IV. CONCLUSION

The PWHT treatment at temperatures of 400, 500, and 600°C with holding times of 1, 2, and 3 hours has proven effective in enhancing the corrosion resistance of AISI 1020 steel welded using the SMAW method. The improvement in corrosion resistance is attributed to the increased homogeneity of its microstructure, namely the distribution of ferrite and pearlite phases, and the elimination of residual stresses caused by thermal cycles during welding.

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